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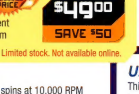

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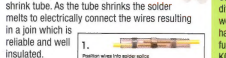

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Ref: SC Magazine Apr/Mar 2012

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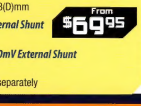

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Publisher's Letter

Australia has missed out on the Square Kilometre Array

Some weeks ago when the announcement about the Square Kilometre Array was reported in the media, touting it as a win-win for all concerned, I thought, "Nah, that can't be true; we must have lost". And so it has turned out to be. In fact, when the announcement was delayed from the original date in February, I then had serious doubts about whether it would come to anything, as far as Australia was concerned.

Most of these doubts had to do with the fact that we were competing against Africa and that the project was funded by a group of nations who might be more likely to favour Africa out of political considerations. And while we may never know the details of the discussions in the meeting, those doubts have turned out to be well-founded. So as soon as the announcement was made, I asked Geoff Graham, who wrote the original story on the SKA in our December 2011 issue, to find out the details. You can see more in the story starting on page 16 of this issue.

My initial reaction to the announcement was to be a little bitter but after a moment's consideration, I had to conclude that it was probably naïve to expect otherwise. So what are the good aspects of the story? By far the best aspect is the fact that Australia has already built a major radio astronomy observatory (ASKAP) and that work has started on the supercomputer installation. Moreover, because ASKAP is Australian, it should not be subject to all the drawbacks of a multi-national project, so we can forge ahead and build on our already considerable expertise.

Apparently the SKA committee proposes that the ASKAP be somehow incorporated into the SKA. My reaction is "Why would we want to?". There has to be considerable doubt whether the SKA will ever be built in Africa, given that most of the funding countries are presently in all sorts of economic and political difficulties and Africa is a politically unstable continent at the best of times. There are 20 countries in the SKA project (seven in the core group) and the total cost of the SKA is projected to be $2.5B or about $100M to $200M for each country. Australia has already spent $220 million on the ASKAP so it seems that Australia has already paid its share and we have something to show for it!

What Australia really should do is to build its own SKA, including the dishes that were planned for New Zealand. Maybe we could prune the overall cost to a more manageable billion or thereabouts. That would be small change to our current Federal government, given its appalling waste of money on so many half-baked projects.

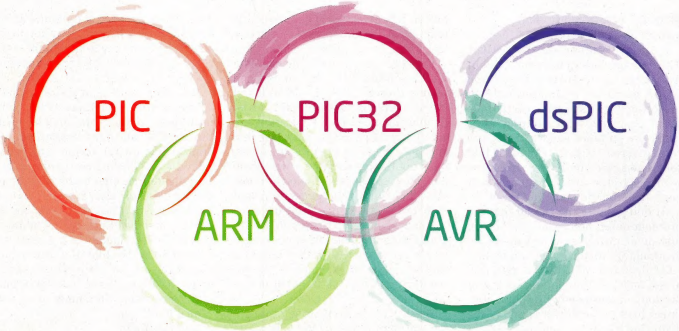
Flashing lights at school crossings

Unfortunately, wasting money is not the exclusive preserve of the Federal Government; state governments do it too, as evidenced by our story on this topic beginning on page 12. It simply beggars the imagination as to how the NSW Roads & Traffic Authority could make such a meal of a simple concept like flashing lights to warn drivers about the 40km/h speed limit at school crossings. As Peter Olsen has shown, it ain't that hard.

Sure, the RTA's version has a few more bells and whistles but even allowing for that, you cannot justify the huge difference in cost or the long delays in installing the lights at all schools. On the other hand, only this morning, as I was collecting the mail and wending my way through all the barriers of a council paving project, I could see why. There was the typical situation whereby one person in a fluorescent jacket was actually doing work while three others looked on and a fourth stood next to the road holding a sign telling the traffic to slow down. How quickly would the job be done if all five people in the fluoro jackets were actually doing physical work? Will this endemic culture of abysmally low productivity in government activities ever be fixed?

Leo Simpson

2012.
Olympic year



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Mains AC waveform distortion was not an April Fool story

I am a member of the CMCA (Campervan and Motorhome Club of Australia) and regularly follow the CMCA members' forum. Recently on the forum there have been discussions about problems with running some loads on portable generators of the "non inverter" variety. The loads that sometimes give trouble are appliances with electronic control circuits that have switchmode power supplies.

At one point, I mentioned that the problem might be caused by the fact that such power supplies might be introducing "distortion power factor" (DPF) into the AC power circuit due to the fact that they (along with gas-discharge lighting etc) present a non-linear load to the power source, thus distorting the AC waveform.

Now, I'm unsure how this might affect the operation of the power supply (maybe it is a victim of its own DPF) or perhaps the introduced distortion is affecting the AVR in some generators. On a small "closed" system, like a washing machine as the only load on a generator, the effect could be quite severe. In most cases, the addition of a purely resistive load, like a small heater, will at least allow the washing to be done but unnecessarily makes a lot of heat in the process.

I'm not even sure of the mechanism which allows this "fix" to work. I would love to have the facilities at home to do some experiments in order to investigate further (I am now retired). Linear power factor mismatch, such as capacitive or inductive loads, does not distort the power waveform but does, of course, adversely affect the efficiency of the generation and distribution system, as you suggest.

I am well aware of the problem with cheap generators and their poor regulation and generally "filthy" output. I own one myself to keep the fridge going during our all too frequent power failures!

However, I think there is more going on here. Some of the generators involved are quite expensive well-known brands such as a 5kVA Onan (American) running a microwave oven and the most recent incident involved a $3000 or so 4.5kVA Honda-powered unit (I forget the brand name) which quoted output harmonic distortion at less than 5%. That Honda would not start a little Dometic (designed for RV use) washing machine (800W) without a fan heater running at the same time. It can be quite a frustrating problem as sometimes you never know what appliance will run with which generator without a trial run.

However, I read your piece entitled "Why is the AC Mains Waveform Distorted?" in the April 2012 issue of SILICON CHIP and I made reference to your article on the forum and mentioned a few of the main points in it. One member replied to the effect that he would tread warily as he knows the Publisher of SILICON CHIP has a sense of humour and that the month of publication of the article may be significant.

I would really like to know if the article was indeed serious journalism or not. It certainly sounded serious but then I guess that is the mark of a good "April Fool" gag.

Rod Goodwin,
Tinana, Qld.

Comment: no, it wasn't an April Fool's Day gag.

Clock radios gain time with grid-feed inverter

As an aside to Leo Simpson's article on "Why is the 50Hz AC mains waveform distorted" (April 2012) I recently had a solar system installed that has

Drawbacks of solar panel installations

I love to hear about people that say that the solar panels generate power for the house and put the remaining excess back into the grid. Here is a question for you: if that is so, then why is it that if the power on the grid has a blackout during the day, your power goes out too? Shouldn't your house be OK running on the power from the panels?

I rang a company about this and the idea is quite simple. You generate power through the solar panels. This feeds straight into the power grid, not to your house power supply. You then suck it back off the grid to use. You get paid for the power out and pay for the power in. So I am told that the power produced by the panels is not for your house; it's for the energy grid.

We have also been told that the feed-in tariff will reduce as more people go down this road of solar. A few people doing it means a high price for the feed-in but as more people add to the system, they can produce more power and therefore pay less.

You also have to be careful on how much you produce. A friend has 24 panels and is well in credit with the power company. However, here in WA if you produce too much, then Mr Taxman looks at it as a business of producing power for profit, so any income or credit received from the over-supply can be assessed as income to tax you on.

Also, my parents were looking at getting them but if they produce any power excess and get paid for it, they would have their pension reduced as the government regards that as income too. These are a few pitfalls I know of in WA, so check on it first!

John Rumming,
Stratton, WA.

Comment: as has been previously discussed in these pages, grid-feed inverters will not operate if the grid itself is down. They cannot be isolated to power a single household.

produced an interesting side effect on the mains supply that remains unresolved. In April we had a 1.56kW solar panel system with a 4.2kW Growatt inverter (MTL) installed at my home. A couple of days after the system was installed I noticed that the two clock radios in our house had each gained about 12 minutes. We have had the radios for a number of years and they have never gained before.

I reset the clocks at approximately 1800 hours (6pm). At 0700 hours the clocks were correct but at 1800 hours they were both approximately six minutes fast again.

Given that the clock radios use the 50Hz mains supply as a reference for the clock function, it seems logical that the inverter is causing the problem since it is the only new item connected to the system. The frequency display on the inverter hunts between 49.9Hz and 50.0Hz and this is as I would expect.

It seems to me that the inverter has a fault (possibly a latent defect in the design) that is imposing some form of harmonic distortion that is superimposed onto the sinewave that it is designed to produce (if indeed it is a pure sinewave inverter). Since the system is under warranty it is beyond my scope to investigate inside the "box" but a review of the mains frequency shape using my 20MHz oscilloscope shows some distortion and clipping to the peaks of the sinewave but that distortion (similar to that shown in Leo Simpson's article) is there even when the inverter has switched off at the end of daylight.

I think that more sophisticated test equipment than I have access to is

Phono inputs on vintage radio chassis

As an old time wireless man and with no criticism of Rodney Champness (he wasn't there at the time and I truly admire his work), the following may be of interest to your readers with regard to his column in the May 2012 issue.

Provision to connect a record player to a radio without audio input switching was an economy measure used by some manufacturers. Radio designers would assume that the record player would employ the then virtually standard magnetic pick-up. Such pick-ups had a coil resistance of a few hundred ohms and when connected would form the low end of a voltage divider with the very much higher value feed resistor from the diode detector (R7 in the Breville 730).

This resulted in only a few millivolts of tuner output to the audio input; easily swamped by the pickup's much higher output and effectively inaudible. Certainly, a high impedance crystal pickup would have allowed severe tuner breakthrough but they were rather a rarity in Australia in those days.

Many thanks to all at SILICON CHIP for your great publication.

Graeme M. Duncan,
Otago, Tasmania.

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Mailbag: continued

Good rear vision may need up to eight cameras

I am writing in reference to the Publisher's Letter in the June 2012 issue on the topic of visibility in cars and the suggestion for rear view cameras. In the 1960s, the "A", "B" and "C" pillars in cars were reduced to the point where their width was less than the distance between the average adult's eyes. The apex of this design "feature" was with the Citroen ID/DS cars where both the "A"and "B" pillars, left and right, were so narrow that no item was hidden from the driver. Now the pendulum has swung to the point where roll-over protection for the occupants is more important.

This means that in my 2½ tonne 4-wheel drive I can lose an oncoming car if it is turning across me! The trucks that I drove over the best part of two decades had two mirrors (one flat and one convex) on each side but it was well and truly possible to lose another vehicle. The most dangerous place for a small vehicle is against the left hand door, generally under the mirrors.

One supplier of "reversing cameras" offers a solution: cameras on the front guards, pointing backwards, with others in the traditional position to get passing/passed traffic, a camera *under* the tray and a roof clearance camera. Total coverage is up to eight cameras with a minimum of six recommended. That is a lot of dashboard space to get a meaningful picture. (Bad pun, sorry!)

Also, for the complete picture, they suggest a recorder with 48 hours capture; programmable, of course. At this point, the weight of cameras, wiring and other hardware is possibly heavier than the glass!

Brian Wilson,
Curtin, ACT.

Comment: hi-res CCD cameras are now very small. Just consider those in iPhone and Android phones and in laptops. The likely weight of six or eight cameras with supporting electronics would be quite low and might enable significant savings in fuel usage if the large external mirrors on buses and trucks could be eliminated.

required to get to the bottom of this mystery.

The matter was referred to the company that installed the system but their remedy was to offer me $100.00 to buy two new clock radios and would do nothing to verify the cleanliness of the inverter output. My next action was to contact the supply authority and their initial response was that the inverter was not their responsibility and I would have to go to the company that installed the system to have it fixed.

I then explained that if enough of these inverters were connected to the main supply system, the resulting noise on the 50Hz waveform could interfere with their control signals and surely they, as the supply authority, were con-

cerned that any equipment connected to the mains only produced a "clean" 50Hz. At this stage the matter became too technical for the phone operator and she promised that the matter would be raised with the supervisor on the next working day and they would get back to me.

I guess the bottom line is I am getting a reduction in my electricity bill for connecting a solar system to the network and nobody is really interested if there are all sorts of harmonics on the waveform as long as it is 50Hz. I am waiting with some interest to see what happens next.

Gordon Dennis,
Mill Park, Vic.

Comment: the way in which grid-feed inverters generate a sinewave is similar to that employed by the Induction Motor Speed Controller (SILICON CHIP, April & May 2012) and that means that there will be switching artefacts in the waveform, possibly at frequencies above 20kHz.

It is possible that these switching artefacts from the inverter are interfering with the clocks' function and it may well be that if you fed them via a mains filter then all would be well.

Loudness of TV commercials

With reference to the recent discussion on loud TV commercials, in addition to the already identified use of heavy audio compression and equalisation in TV commercials to make them louder, there are a couple of other reasons for the phenomenon and tricks used by production houses to obtain the loudness effect.

The first has to do with the average volume level of the voice in a movie and some TV shows. In order to leave headroom for impressive sound effects such as explosions etc, the dialog in modern era movies is mostly set at a relatively reduced level and in a single centre channel. Commercial producers not only more heavily compress the announcer's voice, they record it to the maximum possible level in both the left and right channels of the stereo mix.

The end effect is that a voice in the stereo down-mix of a 5.1 or more soundtrack is usually lower in perceived volume than that made for stereo commercial mix. When summed to mono, the effect is even more pronounced, making the commercial mix sound louder again.

Also, the announcer's voice in a TV commercial is usually close-miked, creating a rich proximity effect for mid-bass and so the width of the sound spectrum. This is usually combined with the trick of completely filtering out any very low bass and subsonic frequencies. Why waste energy transmitting audio spectrum that no-one notices is missing and can "distract" an amplifier and speaker from cleanly producing the all important midrange at best volume?

I have been led to understand that commercial producers have even digitally compressed the commercial's audio to MP3 files in order to remove "extraneous" information that wastes audio energy, leaving what's left to achieve slightly higher amplification.

Another trick to increase the perceived volume is to run the final mix through a modulation optimiser/harmonics "smoother" before sending it to the TV station(s). Again the rationale is to ensure the whole audio chain from the

Mailbag: continued

Laptop supply needs an earth to avoid hum

I have recently come back from a holiday in Sri Lanka and while there I encountered a problem with my Netbook and a Logitech USB headset.

In the last two hotels I stayed at, the power points only allowed for Active and Neutral to be connected and not the Earth. Not realising this would cause a problem, I was Skypeing to Australia, only to get a lot of hum from the microphone with very low audio level. I tried all three USB ports, getting the same result.

Unfortunately, not suspecting it was the unearthed power supply causing the fault, my analysis was so caught up thinking the headset was faulty, with everything else working OK, I neglected to do one very important test.

When I arrived home I connected the headset to my HP Laptop. The headset worked perfectly. I then powered the Netbook with the headset, again with no hum and excellent audio. It was then I realised how the Netbook was powered up in Sri Lanka, so with my converter plugs I was able to eliminate the earth connection. The hum returned on both devices.

This revealed what I should have done: disconnect the power supply and run the Netbook on its batteries!

Simon Kareh,
Penshurst, NSW.

transmitter to your speakers is not wasting energy, in this case on spurious harmonics, and so sound louder.

However, the best and yet low-tech trick is to record the level of the commercial audio around 3-4dB higher than the reference tone run during the commercial ID "clapper". All the peaks have squashed so who needs the headroom anyway and, if everything else is referenced to these volume level tones, this commercial has a head start in the volume stakes – despite the transmitter's peak limiter having to be a bit more active to prevent overmodulation.

The sad fact is that because so many factors go into making commercials sound loud it is impossible to legislate for a perception if the transmitted audio is less than 100% modulation and so meets broadcast specifications. Unless SILICON CHIP can come up with a way of exclusively identifying when there are commercials on TV and then have a kit which automatically reduces the volume by 20%, then accurately restores it at the conclusion of the break, the only solution is heavy compression at the viewer's end or the mute button.

Tim Herne,
Calwell, ACT.

Re-creating PACMAN on the Maximite

The Maximite is an amazing little device that can re-introduce the user to those early heydays of the home computer era. I have many fond memories spent exploring, programming and playing on my first computer, a Tandy TRS-80 Model 1 with a whopping 16K of RAM, cassette storage and low resolution black and white graphics.

Sure, it's no match for modern systems with their gigahertz processors, 24-bit high-resolution graphics and immense hard drive capacities but there is something special about playing with computers of this era. There is a sense of satisfaction at being able to achieve something great on such minimalistic hardware. Although the Maximite is far more powerful than my TRS-80 ever was, for me it encompasses those elements of discovery that occupied so much of my time in the early 1980s.

And so, armed with my trusty Maximite, I proceeded to relive that thrill of creating software using the Maximite's BASIC language and what better way than to write a game! I decided to recreate the famous arcade game of Pac-man for the Maximite. "MaxMan" is the outcome!

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Earthing needs good electrical contact

As a regular reader of SILICON CHIP, I always enjoy the Serviceman's Log. However, I query the methods applied for grounding of the "dodgy, dangerous home-made amplifier" as described in the May 2012 issue.

Earthing of mains operated equipment is done for safety reasons, with fault currents in the 100s of amps (albeit for milliseconds until the safety device trips), so low resistance bonding is essential. Earth testing equipment normally applies a high test current to ensure that the earth points are robust enough so they do not fail under a fault condition.

The article refers to using a star washer each side of the earthing lug. However this practice reduces the surface area point contact to a fraction of that if the lug's total surface was in total contact with the chassis (cleaned of paint and other insulating materials.) A star washer has 8-12 high points that would be the only points of contact with the chassis.

The use of the Nylock nut offers no electrical connection as the thread contact area is an insulating material that distorts; increasing friction minimising the likelihood of the nut becoming loose.

A more desirable method of earth bonding is to tap the thread through the chassis for the earth bolt. This increases the area of contact, reducing the earth resistance. If the panel is thick enough, use a countersunk bolt as this increases the surface contact area. The materials used must be chosen to ensure that no electrolysis takes place due to dissimilar materials.

In many situations, a single bonding point may not be sufficient and there is a need to apply additional bonding points to sections that could be separated from the main chassis, such as hinged panels.

Rob Howes,
Ellenbrook, WA.

original game by Namco will see that the maze graphics in MaxMan is identical. All four ghost characters navigate the maze in search of your MaxMan character and will give chase when they find him. I've included many of the character animations from the original such as the ghost's eyes looking in the direction they are moving and the famous chomping effect of the main player's character.

Additional features include sound effects and support for two types of joystick interfaces: Atari switch type and the use of the Nintendo Wii Nunchuk controller. Keyboard control is also available using the cursor keys. Information on these interfaces is available from the Maximite forum.

Considering that it runs completely in interpretive BASIC, the game runs quite well on the little Maximite, something my TRS-80 couldn't do unless you delved into the voodoo art of Assembly Language! The game can be downloaded from the Maximite website and requires version 3.1 or greater of the MMBASIC firmware. It also seems to run on the many Maximite clones.

Most kids today who have grown up with modern 3D gaming will look at this game and laugh but those of us who grew up during these evolutionary years of video gaming will appreciate the achievement.

Maximite Forum:
www.thebackshed.com/forum/forum_topics.asp?FID=16&PN=1
www.thebackshed.com/forum/forum_topics.asp?FID=16&PN=1
Latest Firmware:
www.geoffg.net/maximite.html
Game Download:
www.maximite.com.au/

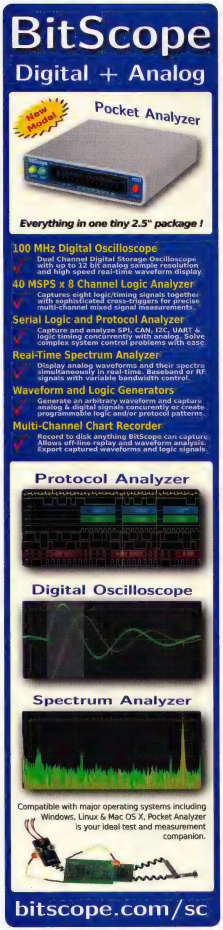
Nickolas Marentes,
Holland Park West, Qld.

Failure of credit card chips

With reference to the letter on credit card failure on page 106 of the May 2012 issue, I have also experienced failure of a credit card chip but I think that there is a mundane explanation.

I used to carry my wallet in the back pocket of my trousers. Repeated flexing upon sitting down would seem a very likely cause of failure. I now carry my wallet in a side pocket and have had no more trouble.

James Goding,
Carlton North, Vic.



Mailbag: continued

Sound levels are indeed a sore point

It seems I erred in dissenting with the editor of SILICON CHIP. I refer to the Publisher's Letter in the May 2012 issue and my own letter in the April 2012 issue. Therefore I need to become realistic, "get real" and "get a life". Apparently I also "do the work". According to the previous editorial about this issue, I may also be stupid or deaf or both. Just how many insults do I need to take because of my opinion?

No, I don't work in theatre running the sound; never have, never will. I have, as a volunteer, been associated with amateur theatre production, so have gained some insights as to how such things come about. I have worked with international touring bands. I do own a PA for live music. I am acutely aware that it has the ability to be very loud.

In "real life" I am a medical professional with 30 years' experience and held in high regard for my skills. Most days I deal with life and far more often than perhaps one should, death. Compared to that reality, perceived loudness becomes not overly concerning in the greater scheme of things. I think I have a life already.

As stated in my previous letter, to not measure a noise or SPL level gives a subjective opinion only. What one person may consider loud, another may not.

This is exactly the stance of the NSW Government, who says, in essence, that because noise complaints are subjective, noise levels need to be measured before a complaint may be acted upon. See **www.environment.nsw.gov.au/resources/noise/10799Part3nglg.pdf**

Similarly, any venue using sound reinforcement equipment only needs the SPL level (measured in dB) to be under the required local council standard and they can argue against any noise complaint. If you don't measure, you haven't got a leg to stand on! I should have taken the opportunity to expand on that in my original letter.

Regardless of the PA system, it depends entirely on where you are seated as to the SPL you will be exposed too. I did touch on this previously. SPL exposure also depends on on-axis exposure or off-axis exposure, and cabinet response.

The highest SPL will be at one metre from the source. Each doubling of distance from the source leads to a reduction in SPL of 6dB. Depending on which source you use and which criteria, some would argue that a 6dB reduction is halving the volume.

So, as an example, if the PA is 100dB SPL at 1 metre, at 2 metres it's 94dB and so on.

If the theatre is 64 metres deep, the SPL at the back will be 70dB, equivalent to the upper end of someone who speaks loudly, or less than your average lawn mower.

Noise exposure levels and exposure time for damage say that at 94dB, one hour of listening can be had before damage to hearing occurs. At 85dB that listening time becomes eight hours before damage. For more information: **www.nal.gov.au/hearing-loss-protection_tab_noise-exposure.shtml**

Hearing perception and reality don't match up either. Most humans cannot discern a volume increase of 1-2dB. 3dB may only be "noticeably louder", in other words, purely subjective. Your readings will need to be A-weighted.

Grant Bunter,
Batlow, NSW.

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Using a bright LED in a slide projector

I noted a question in "Ask SILICON CHIP" about possibly using a high-power LED in a projector. I have done exactly this, installing a bright LED in an old projector.

The LED was a cool-white Cree CXA2011 (which may have been the only one in Australia as I can't see any current supplier). It is being run at 20W, which is half its rated power as I am being conservative in what the heatsink can dissipate. As you pointed out, the projector fan would probably allow the full 40W with a small heatsink but I'm not taking the chance.

Even at half-power the light is extremely bright. It projects an image the size of a 106cm flat-screen TV; easily viewable in a darkened room.

There are a few things to consider. In my case the projector optics are optimised for a specific 300W, 3300K projector lamp. The lamp has a filament arranged as an approximately 12mm square array which fortunately is about the same as the Cree LED active area.

After experimentally positioning the LED, it was concluded it had to be very close to where the lamp filament should be; even a few millimetres in any direction resulted in uneven light distribution. This may be an issue with LEDs with different active areas.

A trickier problem concerns the spectrum of the LED, which is very different to that of an incandescent lamp. Blue and red are dominant with a dip in the green area. The cool-white LED was in retrospect a poor choice

for a replacement as it is blue dominant; there are others in the range that have a better balance between red and blue but the low green output is still a problem.

The projector included a filter that presumably was to compensate for the red dominant incandescent light. Removing it improved the image but the colour balance is still unsatisfactory.

My original intention was to project approximately 650 slides and photograph the images. Although this worked, it was difficult to get an image that was in focus across the whole screen. The depth of field for the projector lens was quite small and if the slides weren't flat, some part would be out of focus. Also, the axis of the projector and camera are different, so there was always a small keystone error (the projector has no keystone correction).

Another problem I encountered early on was that the vibration caused by the fan was enough to slightly disturb the camera which was on a mount on the same table. This caused a small amount of blurring. This was mostly overcome by mounting the camera and projector independently although I suspect the slide was also vibrating slightly.

After further experimentation, a better solution was to back-light the slide, and photograph it directly. This was done by aiming the projector at a closely positioned white piece of paper, producing a very bright square of light slightly larger than the slide. The slide was placed so that it was fully backlit by the square of light.

Fortunately, the camera plus a lens from a cheap telescope enabled the capture of an approximately 2000 x 3000 pixel image which was well focussed. The camera allows a custom white balance to be set, which compensated in part for the unbalanced light source. The vibration problem was completely eliminated.

The camera also was able to compensate for a wide variation in original exposures. Even with this amount of manipulation before capture, it was still necessary to post-process most images to improve the colour balance. The results are mainly limited by the quality of the originals, which is about all one could wish for.

Alan Cashin,
Islington, NSW. SC

Old TVs offered free to a good home

Would you please let your readers know that I have four black & white valve TV sets, free to a good home: a Kriesler 79-3 low-boy with power tuning, remote, diagrams, cabinet good and working; Philips 23CT8-222 low-boy with power tuning, remote, cabinet good and working; an Astor TV/stereogram combo (working) and Precedent TV/stereogram combo (untested).

I can be contacted by phone on 041 7874 037.

Colin Lark,
6 Royal Admiral Place,
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Peter Olsen and his Flashing School Lights

If you're in NSW, you may have seen those "check speed" signs with flashing lights mounted near the large "school zone" signs which mark the areas around schools where children will be present before and after school. They're the result of a lot of political pressure – and heartache – by Peter Olsen over the past six years. Of particular interest to SILICON CHIP, they're powered by PICAXE microcontrollers.

Most people acknowledge that flashing warning lights in school zones will alert drivers of the need to slow traffic down and therefore, it is presumed, prevent accidents – and save lives.

Much more so, in fact, than the static "school zone" signs we have known for more than a decade.

So if you were the NSW State Government and were given the option of changing your $58,000 lights to $1,400 lights – with proven greater reliability, higher accuracy and a measured lower average vehicle speed, would you do it?

No, you'd embark on an expensive PR campaign to denigrate the alternative lights and their developer, completely ignoring the fact that you, as a Government, had foregone the benefits and were determined to press on with your program, regardless.

More than that, you'd launch a "dirty tricks" campaign to prove that your flashing lights were better, even to the extent of banning use of the others in public streets (current installations have all been on private property).

But first, some background

Peter Olsen first came to public prominence as the organiser of the world-famous "Lugarno Christmas Lights", where not just Peter's house, not just his neighbours but a whole street (it happened to be Maple St, Lugarno – a southern Sydney suburb) rallied together to put on a display of Christmas Lights.

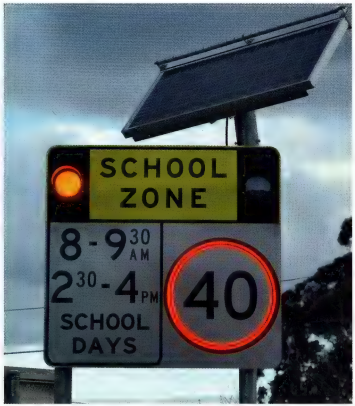
By Ross Tester

Display is a massive understatement – Maple Street had literally hundreds of thousands of lights, with amazing animations, tableaux, cartoon characters and synchronised music.

That not only attracted hundreds of thousands of visitors each year (and created multi-kilometre-long traffic jams – I speak from experience!) but along the way raised hundreds of thousands of dollars for charity.

In 2006, Peter retired and moved several kilometres away.

That same year, he heard that the (then) NSW Roads and Traffic Authority (RTA) was trialling flashing warning lights for school zones. He was flabbergasted to find that the cost of each simple alternate-light flashing sign was (then) $12,000 and set out to prove that reliable flashing lights



Two versions of the NSW Roads and Traffic Authority (RTA – now RMS) School Zone Speed Signs. The one above has no flashing lights but is overwhelmingly the most common today. At right is their latest and greatest version, complete with flashing LED lights, a flashing LED annulus around the speed sign . . . and solar powered. Each sign costs around $58,000. Peter Olsen's simpler version (opposite) costs $1400 – installed!

could be produced for just a fraction of that amount. Based on his experience with computerised Christmas lights, he made his first flashing light signs for just $200.

They were controlled by a 7-day electronic timer. He installed them on eight 40km/h signs, without approval, in mid-2006.

There followed a rather public "stoush" between Peter Olsen and the RTA, with the RTA "ripping out" Peter's signs, Peter re-installing them and the RTA pulling them out again.

A series of meetings with the RTA and Minister for Roads finally resulted in an approved "trial" of eight sets of lights.

Peter developed a fully automatic PICAXE based controller for the signs, complete with GPS for accurate timekeeping. He signed a contract authorising the RTA to use his technology, royalty-free, forever, if they wished.

The lights proved to be 100% reliable for the four years that they were in operation – except for a couple of problems where power supplies, provided by the RTA, failed.

According to a government media release, the RTA's own flashing signs are only 98.2% reliable.

In 2009, after becoming frustrated that the RTA was still refusing to use cheaper technology, Peter started installing signs of his own.

He first studied the law carefully to find out what was legal. He adopted the words "Check Speed", to avoid the prohibition on installing "prescribed signs". He also installed them on private property, where they were beyond the RTA's reach.

The lights cost around $1,400 per sign, which includes the sign and pole to mount it on. Peter points out that if the lights were installed directly on the existing 40km/h signs, the cost would be under $1,000 each.

Fast-forward to 2012

The NSW Government has changed, the RTA has been replaced by the Roads and Maritime Services (RMS).

Unfortunately, the one thing that hasn't really changed is the bureaucratic attitude to Peter Olsen's lights. They still want their own!

RTA Lights vs Olsen Lights

FEATURE	RTA LIGHTS	OLSEN LIGHTS
Average cost per sign	$58,125	$1,400
Cost to taxpayer per sign	$58,125	$0
Annual maintenance cost per sign	$2,545	$0
Reliability	98.2%	100%
Average reduction in vehicle speed	4.3kmh	6.3kmh
GPS receiver for absolute timing accuracy	No	Yes
Average fault repair time	2 days	0 days
Average time from school request to install	2 years	2 weeks
Provide to any school in NSW on request	No	Yes
Total school zones installed as at May 2009	291	21
School zones installed from Jan-May 2009	25	17
Total staff in organisation doing installs	7,000	1

Operating costs

We've already looked at the cost to produce the signs – but what about the cost to operate them?

Virtually all signs installed by RMS are solar powered, with power saving and "green" credentials being the usual reasons given.

Peter Olsen claims this is bunkum. Solar-derived power, even on the small

One of Peter Olsen's "Check Speed" signs, installed on private property but as close as possible to the non-flashing RMS School Zone signs.

scale required to run the lights, is significantly more expensive to install, is significantly less reliable than a mains supply and requires more maintenance (eg, to replace batteries at least every three years).

Not only that, the solar panels themselves are subject to theft, vandalism and hail damage. And when the signs are inevitably hit by errant vehicles, they are a lot more expensive to fix or replace.

Peter Olsen claims that solar-powered lights are around 200 times times more expensive to maintain than mains-powered lights. And as for "green", he asks "what about the cost to manufacture the solar panels – or the cost of replacement (and disposal) of batteries and their toxic chemicals?"

Olsen's lights are powered by a simple 12V supply direct from the mains – and as the lights have been overwhelmingly installed on private property, the power required is a "gift" from the property owner.

But what is the cost of that power? LEDs don't take a lot: the 100mm lights draw just 8W and the 200mm 12W.

Given the fact that they are on for only three hours per day and then only on school days (around 205 days per year), the maximum electricity cost (including the controller and GPS receiver for accurate timekeeping) is just 92c per annum for the 100mm lights and $1.38 for the 200mm version.

Mr Olsen is pushing for the RTA to use mains power where possible – and points out that many 40km/h signs have 230V power lines directly overhead!

Lights cost

We mentioned at the outset that the Government's school zone lights cost more – a whole lot more – than Peter Olsen's lights. Through a series of press releases, the RTA (the previous Government's department which has now become the RMS) has muddied the water significantly. Peter calls it "dirty tricks".

Peter Olsen offers his lights to schools for $1400 each – installed. He urges schools to obtain local sponsorship, which in the main has been very successful – Rotary clubs sponsor many of them.

The RTA's own figures reveal a cost to the community of $58,125 each for the lights installed during the last term of the previous government. ($46.5M for 800 signs). That covered 400 school zones, less than 4% of the 11,000 school zones in the state.

The new government has budgeted $17 million for the installation of lights over four years. By June 2015 it expects to have 1390 school zones equipped with their lights, around 700 more than when it took office. That amounts to $24,285 per zone – but still only covers 13% of school zones. That $17M could pay for Peter Olsen's $1,400 lights at over 6,000 school zones instead of just 700.

Reliability

The RTA claims their light design, with back-to-base monitoring of faults, is essential for safety. In fact, they claimed "it alerts the RTA to any problems immediately" and "is essential to ensure our children remain safe". In an apparent direct attack on Peter Olsen's much simpler (but demonstrably more reliable design), they said "we cannot install potentially usafe, unreliable and infrequently monitored systems when it is our children we are trying to protect."

What they don't explain, as Mr Olsen points out on his website, is why many sets of their lights, with back-to-base monitoring, have been out of action with faults for up to a week at a time.

The Olsen lights are not back-to-base monitored. He maintains that with literally hundreds of parents and children (not to mention school staff) passing by the lights every day, the RMS would be very quickly be notified of any fault.

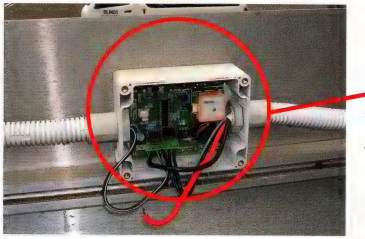
But so far, there hasn't been a breakdown. His lights have been 100% reliable, versus the RTA's 98.2%.

How long does installation take?

It has taken an average two years from the time a school requests RTA lights until the time they are installed – and then only if the location meets the RTA's quite specific requirements.

The time it takes for the Olsen lights is usually less than two weeks – and that's for any school that asks for them.

He installed four sets of lights at Burraneer Bay Public School within 3 days of the recent accident that left a 6-year-old boy critically injured. He funded those lights himself, after hearing that the school had been begging the RTA/RMS for lights for nearly two years.



The electronics is fully self-contained apart from the off-unit 12V DC plugpack supply. It all fits into a small IP65 box which can easily be mounted on the back of the sign.

The main location difference (apart from obvious design) is that the Olsen lights need to be installed on private property – earlier lights installed by Olsen on public property were ripped down by the RTA.

Effectiveness

Without policing and/or speed cameras installed, flashing lights are not the panacea we'd like to think they were. But ANY reduction in vehicle speed through school zones is worthwhile. Surveys reveal the RTA lights show an average 4.3km/h reduction in vehicle speed. Olsen's lights showed an average 6.3km/h reduction – almost 50% better.

The lights also allow drivers to avoid unnecessary fines, especially on days such as "pupil free" days when school zones are still in operation.

What's in the designs?

The RTA issued very specific requirements for tenderers to meet for their lights, including solar power where possible and having radio back-to-base monitoring. Their lights are housed in a large box attached to the back of the signs or the mounting poles.

Originally the electronics merely powered alternately-flashing sets of lights but more recent designs also flash an annulus of red LEDs around the '40' (ie, 40km/h) in the centre of the sign.

Olsen's design is much smaller – and much simpler – than the RMS's. Based on a PICAXE microcontroller, it (and its GPS receiver) fits into a small IP65 box which can be mounted on the back of the sign or off it.

There are two basic parts to it: first there is the time and date-keeping, which ensures that it turns the lights on and off at the right time of day on school days only. The controller is pre-programmed with school and public holiday dates four years in advance, which is as far ahead as the dates are gazetted.

The second part of the design is the actual switching on and off of the lights, which is a simple task for the PICAXE microcontroller. Unlike the RTA's lights, which simply alternate, Mr Olsen's lights operate in a much more eye-catching strobe mode. A side benefit is that it halves the power consumption.

As anyone who has used a PICAXE microcontroller (and SILICON CHIP projects have used plenty!) will attest, reprogramming is a very quick and easy task, although no changes to the actual code have been necessary in the six years that Mr Olsen's lights have been operating.

He simply has to upload new holiday dates every four years using a short-range transmitter. He does that when he attends the site for routine preventative maintenance.

Because the Olsen design is powered by 12V DC, there is no need for a power supply inside it – further contributing to reliability due to less heat.

The GPS unit incorporated into the Olsen design means that its timekeeping is 100% accurate. Unlike the RMS lights, it does not rely on any radio control nor does it have back-to-base fault monitoring.

The future?

In the past, the road and traffic authorities have been particularly dogmatic about the Olsen signs being inferior, potentially unsafe and so on. They apparently haven't quite declared the signs illegal but have skirted around the subject with implied warnings.

He goes to some length on his website to explain the difference between proscribed traffic signs (which are the sole province of the authorities) and his signs.

The result appears to be some form of "tolerance" between those authorities and his signs.

This may also have something to do with a change of Government in NSW and also the change of the department itself.

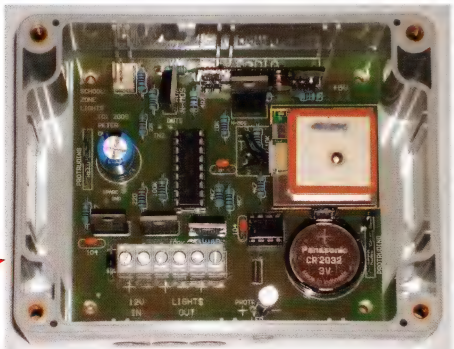
Peter Olsen has obviously been a thorn in the side of the RTA/RMS, but along the way has attracted some heavy-hitter supporters in the media – radio 2GB's Alan Jones and Chris Smith, for example, have interviewed Peter many times.

He's also attracted sponsorship for his signs from unlikely sources – a large legal firm, for example. He's quick to point out that they would hardly get involved if his signs were illegal.

He is still offering his flashing school zone signs to any school who wants them – and while the school has to pay for them to be installed, it's dramatically less than the community has to pay for the "approved" signs.

There's a page on his website containing all the documents needed to order signs.

Contact www.schoolzonelights.com.au or phone Peter Olsen on 0414 538 404 or (02) 9599 1811 for more information – or to order signs for your local school!



The electronics consist mainly of the PICAXE chip which drives Mosfets which in turn control the high-brightness LEDs in the sign. A 433MHz receiver (top of PCB) allows "ground level" reprogramming, while the large "box" on the right side is the GPS receiver which is used as a time reference.

The Square Kilometre Array – Australia Misses Out

By GEOFF GRAHAM

One of the first ASKAP dishes to be constructed at the Murchison Radio-Astronomy Observatory in Western Australia. Photo credit: Paul Bourke and Jonathan Knispel. Supported by WASP (UWA), iVEC, ICRAR and CSIRO.

Most readers will have heard of the Square Kilometre Array (SKA) radio telescope project which SILICON CHIP reported on in the December 2011 issue. It was supposed to be a bidding contest between Australia and South Africa. In simple terms, South Africa won and we lost. But that's not the end of the story.

An artist's impression of the high-frequency dishes that will be installed in the Karoo desert in South Africa. These are the type of antenna that we normally associate with a radio telescope. Photo credit: SKA Organisation/Swinburne Astronomy.

THE SKA IS A $2.5 billion international project to build a giant radio telescope using thousands of individual dishes spread over thousands of kilometres. Using immensely powerful computers, yet to be developed, scientists hope to combine the signals from all these dishes to give ultra-clear and sensitive images of the radio sky.

With such a big project on offer, the competition for the right to host the SKA was fierce and it came down to a contest between South Africa and Australia/New Zealand. Australia's proposed site was in the Murchison region of Western Australia and we even went as far as building the $220 million ASKAP radio telescope on the site, partially to demonstrate our capability in this field.

As was widely reported on 25th May 2012, the SKA Organisation decided to share the telescope between the two contenders. This seemed like a simple enough decision and a win-win for both sides. But is it?

Making the decision

To evaluate the competing bids, the SKA Organisation (headquartered in the UK) formed a Site Advisory Committee and they concluded that either site was suitable. In the end, their recommendation was to host the project in South Africa. This advice was based mostly on technical factors, which included a more favourable layout of the array in southern Africa and lower operating costs (political, socio-economic and financial factors represented just 2% of the decision).

By many reports, this recommendation led to a fierce debate within the SKA community, with non-technical issues being raised. According to reports, the debate became acrimonious, with allegations of dirty tricks and political high-handedness. The public was unaware of this battle but a sure indication was the premature leak of the committee's recommendation to The Sydney Morning Herald in March.

The final decision on the telescope's location was the responsibility of the international members of the SKA Organisation who did not bid (Canada, China, Italy, the Netherlands and the United Kingdom). Their debate was held behind closed doors but it has been reported that the three European countries favoured South Africa, perhaps because it was closer to Europe and they would have better control over the project. Reports also claim that Canada and China favoured the Australia/NZ bid because of the better infrastructure in Australia and the political instability of some countries in the South African consortium.

Faced with this stand-off, the decision was a typical bureaucrat's solution; split the project between the competing countries.

Practical results

The next issue for the SKA Organisation was how to divide up the project. Because Africa and Australia are on different parts of the globe they see different parts of the sky at any one time. This means that the SKA could not simply share the telescope's dishes between the countries, as they all had to be looking at the same part of the sky at the same time.

So the decision was made to deploy the main telescope with all the high-frequency dishes to South Africa while Australia would have the low-frequency aperture array scheduled for deployment later as part of Phase 2. In practical terms, this means that the majority of the telescope will be built in Africa. The official statement describes it as a split of two thirds to Africa and one third to Australia/NZ but given that full construction of the less important low-frequency aperture arrays will only commence in Phase 2 (around 2020), most of the observable activity will be in Africa.

In Australia, this was reported as

The Dense Aperture Array will be used to survey the mid-frequencies and will also be installed at the SKA site in the Karoo desert in South Africa. Photo credit: SKA Organisation/Swinburne Astronomy.

a "win-win" situation but in South Africa it was heralded as a triumph for Africa while deploring the associated compromise forced on to them by political expediency.

For New Zealand, the result is quite disappointing. The low-frequency aperture array will be in the Murchison region of Western Australia and it is difficult to see how this could be extended to New Zealand.

This map shows the proposed layout of the high-frequency dish array throughout Africa. Credit: SKA South Africa.

Three types of detectors

The SKA was envisaged from the start as consisting of three types of detectors:

(1) The high-frequency dishes, ie, the traditional steerable dish types that most people associate with a radio telescope;

(2) A medium-frequency array covering roughly 0.5GHz to 3GHz. This will be primarily a survey instrument, exploring the evolution of galaxies, dark energy, transient sources and the realm of strong gravity; and

(3) A low-frequency aperture array covering about 70-300MHz which will be used to investigate the epoch of reionisation and some transient sources.

The high-frequency dishes and the medium-frequency array will be installed in Africa while the low-frequency aperture array will be installed in Australia. Both the medium and low-frequency arrays are new technology and both countries will experiment with them in Phase 1 but full construction will only start in Phase 2.

The low-frequency aperture array to be installed in WA will probably consist of arrays of "droopy dipoles", one for each polarisation and arranged into stations in a fixed pattern on the ground. The signals from each dipole will be combined using computers to observe a number of large areas of the sky simultaneously. This is different from the traditional telescope where a dish is aimed at the source and the signal is bounced from its surface to the focus where it is captured.

The future of the SKA

The decision on where to locate the SKA is not by any means the end of the story. One of the big issues facing the SKA will be to obtain sufficient funding to begin construction. To date, only a small amount of seed funding has been provided by the SKA member countries and this has been used for items such as the construction of the SKA's headquarters and staff salaries.

Soon, serious funding of hundreds of millions of dollars will be required and it is difficult to see how hard-pressed countries like Italy and the UK can find this sort of money when their citizens are forced to suffer under government-imposed "fiscal austerity". Non-European countries like the USA are not in a much better position and given the world's present financial crisis, $2.5 billion is a lot of money to spend on something that could be

Above: artist's impressions of the low-frequency array that's destined for the Murchison in WA. Phase 1 of the SKA project will involve experimenting with them while construction will start in Phase 2 (2020 or later). Photo credit: SKA Organisation/Swinburne Astronomy.

Above: an elevated view of four of CSIRO's new ASKAP antennas at the Murchison Radio-Astronomy Observatory in Western Australia, October 2010. Photo credit: Ant Schinckel, CSIRO.

deferred until times are better.

Consequently, it is very likely that the various target dates for the project will slip and that could push out the date for the construction of the low-frequency aperture array in Australia even further than 2020. In fact, it might never happen at all.

Another issue that the SKA has to face is the effects of creeping bureaucracy and national rivalries, some of which has already become apparent in

The Full Statement From The SKA Organisation

The Members of the SKA Organisation today agreed on a dual site solution for the Square Kilometre Array telescope, a crucial step towards building the world's largest and most sensitive radio telescope.

The ASKAP and MeerKAT precursor dishes will be incorporated into Phase I of the SKA which will deliver more science and will maximise on investments already made by both Australia and South Africa.

The majority of the members were in favour of a dual-site implementation model for SKA. The members noted the report from the SKA Site Advisory Committee that both sites were well suited to hosting the SKA and that the report provided justification for the relative advantages and disadvantages of both locations, but that they identified Southern Africa as the preferred site. The members also received advice from the working group set up to look at dual site options.

The majority of SKA dishes in Phase 1 will be built in South Africa combined with MeerKAT. Further SKA dishes will be added to the ASKAP array in Australia. All the dishes and the mid frequency aperture arrays for Phase II of the SKA will be built in Southern Africa while the low frequency aperture array antennas for Phase I and II will be built in Australia/New Zealand.

"This hugely important step for the project allows us to progress the design and prepare for the construction phase of the telescope. The SKA will transform our view of the Universe; with it we will see back to the moments after the Big Bang and discover previously unexplored parts of the cosmos" says Dr Michiel van Haarlem, Interim Director General of the SKA Organisation.

The SKA will enable astronomers to glimpse the formation and evolution of the very first stars and galaxies after the Big Bang, investigate the nature of gravity, and possibly even discover life beyond Earth.

"Today we are a stage closer to achieving our goal of building the SKA. This position was reached after very careful consideration of information gathered from extensive investigations at both candidate sites," said Professor John Womersley, Chair of the SKA Board of Directors. "I would like to thank all those involved in the site selection process for the tremendous work they have put in to enable us to reach this point".

Factors taken into account during the site selection process included levels of radio frequency interference, the long term sustainability of a radio quiet zone, the physical characteristics of the site, long distance data network connectivity, the operating and infrastructure costs as well as the political and working environment.

The agreement was reached by the Members of the SKA Organisation who did not bid to host the SKA (Canada, China, Italy, the Netherlands and the United Kingdom). The Office of the SKA Organisation will now lead a detailed definition period to clarify the implementation.

Scientists and engineers from around the world, together with industry partners, are participating in the SKA project which is driving technology development in antennas, data transport, software and computing, and power. The influence of the SKA project extends beyond radio astronomy. The design, construction and operation of the SKA have the potential to impact skills development, employment and economic growth in science, engineering and associated industries, not only in the host countries but in all partner countries.

the site-selection process. While some major science projects like the Large Hadron Collider at CERN have avoided this problem, the international fusion reactor project (ITER) under construction in the south of France illustrates just what can go wrong with a giant project funded by many competitive countries.

This latter project has had numerous cost overruns and delays, partially due to the bureaucratic squabbles between the seven major countries involved. There are plenty of examples where a section of the project designed and built by one country will not integrate with another section produced by a different country. The has resulted in arguments, accusations and a project that has been delayed time and time again.

Australia's SKA Pathfinder

The Australian SKA Pathfinder (ASKAP) project is currently under construction by the CSIRO in the Murchison region of Western Australia, at the same site proposed for the SKA. Australia has invested a lot of money (over $200M) on this project and it is tempting to ask what effect the recent SKA announcement will have. After all, it was touted as a demonstration of Australia's capabilities in the competition to attract the SKA to Australia.

In fact, with ASKAP, Australia has done a great deal more than South Africa in committing funds and building something concrete.

The ASKAP is a great radio telescope in its own right and it will be many years before the SKA, ultimately to be built in Africa, will be in a position to eclipse it. Even then there is a lot of sky to look at and many scientists will queue up to use the ASKAP for projects that cannot be done using the SKA.

A further vote of confidence in the ASKAP is the fact that the SKA project also plans to invest in it by adding more dishes.

Money well spent

The ASKAP has, and will continue to provide, a solid base for Australia to develop cutting-edge electronics and computer technology, train engineers and keep high-profile scientists in the country where their expertise can help budding scientists. In this regard, the money is well spent, despite the decision regarding the SKA.

Looking further afield, data from the ASKAP and the SKA will be freely available to all scientists, regardless of which countries host the telescopes. Researchers from anywhere will be able to use this data to gain greater insights into the cosmos and have the opportunity to make great discoveries that will benefit all of humanity. SC

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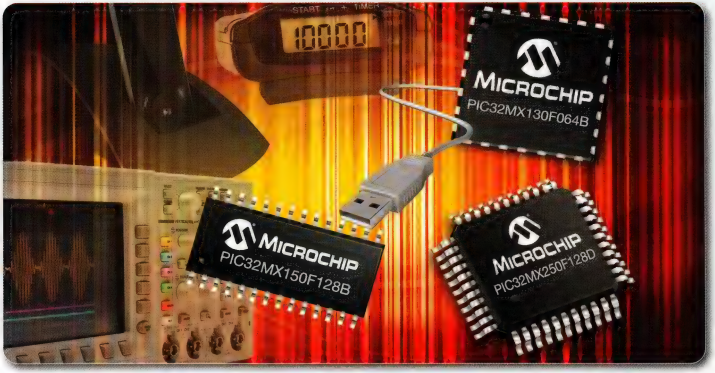

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Stop that dangerous kick-back . . .

Soft Starter for Power Tools

by NICHOLAS VINEN

Does your electric saw, router or other large mains-powered hand tool kick like the proverbial mule when you squeeze the trigger? No matter how firmly you hold it, it will still kick and that can be enough to throw you off a carefully lined up cut. This can be bad enough when you are trying to start an accurate cut with a circular saw but it can damage the job if you are using a tool like a large plunge router. But now you can stop that kick with our Soft Starter for power tools.

Our **Soft Starter project** from April 2012, which tames switch-on current surges primarily in equipment with switch-mode supplies, has been very popular. But readers started asking "what about something similar for power tools?"

Many of the smaller mains power tools these days have speed controllers built into the trigger, so they are very controllable when you turn them on.

But larger power tools such as circular saws, plunge routers, angle grinders and worst of all, large electric drills for concrete core drilling, have a simple trigger or thumb switch which applies full power to the motor. Core drilling is particularly dangerous, as you have to brace the core drill bit hard against the wall or floor and then press the trigger. The resulting torque kick can easily jerk the whole tool out of your hands! And you can be injured in the process!

Why does it kick?

The reason for that enormous initial torque is the very high surge current pulled by a universal (series wound, brush) motor when power is first applied. Because the motor is not rotating, it is not generating any back-EMF to oppose the applied mains voltage and the resulting surge current can easily be ten times the rated current of the motor with full load.

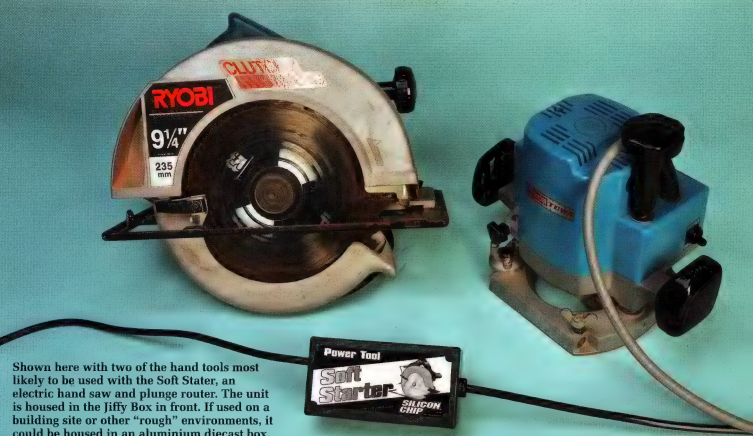
Elsewhere in this article we show some scope grabs depicting these massive currents which luckily die away to much lower values within less than half a second. It is those massive currents which cause the lights to flicker when you switch on a big power tool; the mains voltage sags noticeably.

Features & Specifications

Inrush current limiting:	<20A
Minimum load power:	~100W
Maximum load current:	10A
Minimum tool restart interval:	60s recommended

The cure

Our solution is simple: When you squeeze the trigger switch on the power tool, current immediately starts to flow but is limited to a reasonable value with a big power resistor. Then,



Shown here with two of the hand tools most likely to be used with the Soft Stater, an electric hand saw and plunge router. The unit is housed in the Jiffy Box in front. If used on a building site or other "rough" environments, it could be housed in an aluminium diecast box.

after about half a second, we use a relay to short out the resistor and full power is applied to the motor. By that time, the motor is already spinning at high speed so the big peak current is avoided. The basic scheme is shown in the block diagram of Fig.1.

In this case though, we have not used a big power resistor, simply because a suitable value with sufficient rating would be large and expensive. Instead we have used two large negative temperature coefficient (NTC) resistors in series with the Neutral side of the load (ie, the power tool). These thermistors have a relatively high initial resistance of about 10Ω each and so they limit the surge current to about 11.5A (230VAC÷20Ω).

Now while these thermistors are relatively small, they normally become very hot as their resistance drops. However, we don't give them a chance to get really hot because they are switched out of the circuit after a short delay.

So how do we know when to short out the thermistors? Referring to Fig.1, you will see that there is a current sense resistor in series with the thermistor. This sense resistor has a value of 10 milliohms (0.01Ω) so that the voltage loss across it is quite low. We use this shunt resistor to sense when current starts to flow, immediately after the power tool trigger switch has been pressed.

The sense resistor is connected to a comparator, which works by comparing the instantaneous load current to a reference threshold.

When you turn the power tool on, it will draw a lot of current at first, well above this threshold. Once this is detected by the comparator, it begins charging a capacitor and after half a second, it operates the relay. From that point on, the tool is effectively connected directly to the 230VAC mains and operates as if the Soft Starter isn't even there.

When the job is finished and you release the trigger switch, the current stops flowing and the circuit resets itself, ready to go again.

As long as the tool continues to draw at least 100W (and virtually all do), the relay stays closed. When you switch the tool off, the load current drops to

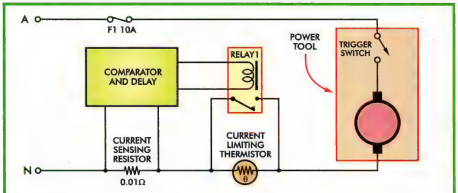


Fig.1: the Soft Starter block diagram. Initially, mains current passes through fuse F1, the power tool motor, a current-limiting thermistor and current sense resistor. A short time after the motor is started, the control circuitry energises Relay1, shorting out the thermistor so the motor gets full power. We actually use two thermistors in series but the principle is the same.

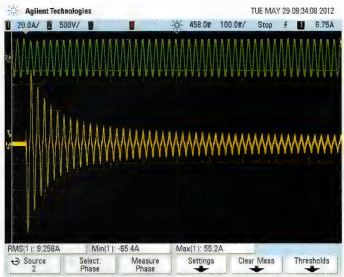


Fig.2: the mains current (yellow) and voltage (green) when starting a 1500W router. The peak current is in excess of 60A, hence the "kick". Current drops as the motor comes up to speed and it develops more back-EMF, opposing the mains voltage and thus limiting the current. Note the triangular shape of the current waveform which is almost in phase with the mains voltage.

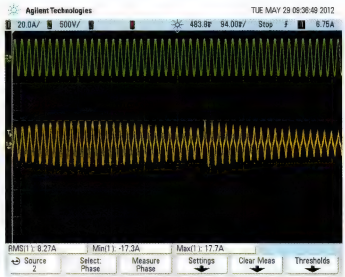


Fig.3: with the Soft Starter in circuit, the current at start-up is much lower, initially just 10A peak. This increases slowly over the first 200ms or so as the NTC thermistors warm up, then for the next 400ms the current draw drops as the motor comes up to speed. You can see the slight increase in current as the relay kicks in after 600ms and then the current drops further as the motor approaches full speed.

zero and the capacitor discharges. After about half a second, the relay opens and the unit is ready to be used again.

Note that if you start and stop the tool multiple times in quick succession, the thermistors won't have time to cool down properly and the starting current on the second and subsequent starts will be higher than the first and so the tool kick-back will be higher. Even though the thermistors only conduct briefly before being shorted out, they still get quite hot in that short time; quick multiple starts means they getter hotter, their resistance is lower and so the surge currents are higher.

So the strategy is clear: to minimise switch-on kick back, don't stop and start the tool repeatedly in a short time. Wait about ten seconds or so between each cut, or whatever.

While this is primarily intended to be used with power tools, there are some other types of load for which may be suitable. For example, it may work with some larger power amplifiers and these could then be switched on using the front panel or remote control rather than having to turn them on and off at the wall, for the Soft Starter to be effective.

But there are some caveats. The main restriction is that the load must have a relatively sinusoidal current waveform and draw at least 100W when on.

Some devices with switch-mode supplies or with transformers feeding bridge rectifiers will not be suitable. Switch-mode supplies with Active Power Factor Correction (Active PFC) should be OK.

The reason is that if the load current is drawn over a narrow part of the mains cycle (ie, near the peaks), the duration of the portion which is above the detection threshold may be too short for the comparator to detect and so the relay will never activate. Active PFC spreads the current out over the full mains waveform, overcoming this issue.

However, the only sure way of knowing whether a given device can be successfully used with this Soft Starter is to try it and check that the relay reliably switches in after the load is turned on. If not, the Soft Starter is clearly not suitable for that particular load.

Circuit description

Refer now to Fig.5, the circuit diagram. The mains input and output sockets have their active terminals joined via a 10A fuse, protecting both the Soft Starter and the load. The earths are joined, possibly using pin 2 of CON1 as a convenient anchor point. This is vital for safety.

The neutral connection is where the soft start action occurs. Initially, the Neutral input (from the mains) and the Neutral connection to the PCB are joined via two series NTC thermistors, TH1 and TH2.

Two thermistors provide better in-rush current limiting than one and also reduce the required cool-down time somewhat.

Also in series with these thermistors is a 10mΩ (0.01Ω) surface-mount resistor which monitors the load current. Its resistance is so low that it has no effect on the load current and dissipates little power (<1W).

When the contacts of RELAY1 close, they short out both thermistors. This has two advantages; the tool gets full power soon after it's switched on and it allows the thermistors to immediately begin cooling down. The relay is rated at 240VAC/16A, which suits loads up to 4000VA.

15A is the highest continuous current available from "large earth pin" power outlets (10A is the maximum from standard outlets) so we don't see any problem with the current limitation.

The rest of the circuit monitors the voltage across the 10mΩ resistor and turns on RELAY1 when appropriate. It is based around two active devices, quad precision comparator IC1 and PNP transistor Q1.

Window comparator

IC1a and IC1b are connected so that if the voltage across

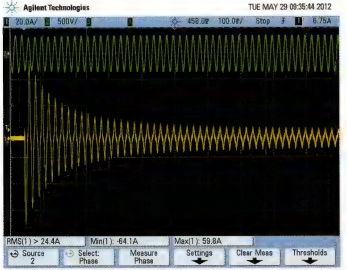


Fig.4: start-up current of a 1750W circular saw without the Soft Starter. This is quite similar to the 1500W router waveform opposite but the peak current is a little higher. Note how the mains voltage (green, top) sags quite markedly for the first few cycles after switch-on due to the huge initial current. With the Soft Starter, the result is similar to the router (see Fig.2).

the 10mΩ shunt exceeds about 3.3mV (ie, a peak load current of 330mA), their common output at pins 1 and 2 goes low. One end of the 10mΩ shunt is connected to ground and the other to pin 6 of IC1b and, via a 1kΩ series resistor, pin 5 of IC1a.

Since the current waveform is AC, the voltage at these pins can be above or below ground, so IC1b checks to see whether it goes above +3.3mV while IC1a does the same below -3.3mV.

These references voltages are derived from the forward voltage of D3 and D4 (around 0.6V each) using 180kΩ/1kΩ voltage dividers, ie, 0.6V x 1kΩ ÷ (180kΩ + 1kΩ) = 3.3mV.

Diodes D3 and D4 are fed from the +12V and -12V rails respectively via 22kΩ current-limiting resistors. Their forward voltages are reasonably stable over a wide range of supply voltages and the expected operating temperature range. The 22kΩ resistors set the current through each to (12V – 0.6V) ÷ 22kΩ = 0.5mA. A small amount of this current flows through the parallel resistors.

Now consider the operation of comparator IC1b. The shunt is connected directly to its inverting input while the 3.3mV reference voltage is applied to its pin 7 non-inverting input. The open-collector output pin 1 goes low when the voltage at pin 6 exceeds that at pin 7. This will occur when the voltage across the shunt is above +3.3mV.

Hysteresis

When the shunt voltage is between -3.3mV and +3.3mV, IC1b's output (pin 1) is pulled up to +12V by a 100kΩ resistor. There is a 10MΩ resistor between this output and the non-inverting input (pin 7) which provides some hysteresis, so that the output does not vacillate when the threshold is crossed.

This resistor works as a voltage divider in combination with the resistors connected to pin 7, which provide the +3.3mV reference voltage. When the output is high, the 10MΩ resistor is effectively in parallel with the 22kΩ and 180kΩ resistors at the anode of D3.

This allows an extra 12V ÷ (10MΩ+ 100kΩ) = 1.2μA to flow through the 1kΩ resistor, adding 1.2mV to the reference voltage, ie, it becomes +4.5mV.

But when the output of IC1b is low (-12V), the 10MΩ resistor sinks a similar amount of current from this point, lowering the reference voltage to around 3.3mV – 1.2mV = 2.1mV. It is the 2.4mV difference between the positive-going threshold (4.5mV) and the negative-going threshold (2.1mV) which provides the hysteresis.

In other words, once the shunt voltage goes above 4.5mV and the comparator output goes low, it must drop below 2.1mV before the comparator output will go high again.

The 3.3mV level is just a nominal voltage and does not actually occur in the circuit.

The operation of IC1a is similar but since it its inputs must be swapped to allow it to act as the other half of the "window", the voltage hysteresis is applied to the feedback from the shunt, rather than the reference voltage.

The 10MΩ and 1kΩ resistors form a divider which has a virtually identical effect on this sense voltage as described above, ie, it raises or lowers it by 1.2mV depending on the output state.

The minimum ±2.1mV thresholds have been selected based on the precision of the LM339A. This has a 2mV maximum input offset voltage with a 5V supply, at 25°C.

Unfortunately, the data sheet is coy about just how this varies with supply voltage and temperature but under our operating conditions, it should normally be below 2.1mV.

This is why we have chosen the LM339A rather than the more common LM339 variant; if the input offset voltage exceeded the window comparator thresholds, either the relay would switch on with no load or it would never switch off once the load current ceases.

(Remember, power is still applied to the Soft Starter even after you've let go the tool's trigger).

Time delay

When the load current is above the stated threshold and the outputs of IC1a and IC1b are low, this charges a 220nF capacitor via the 2.2MΩ resistor and when the outputs are high, it is discharged in the same manner.

Comparators IC3c and IC3d are wired up in parallel and the capacitor voltage is applied to their non-inverting inputs (pins 9 and 11) via a 3.3MΩ resistor.

When the relay is off, the outputs of these comparators (pins 13 and 14) are at around +11.4V, since there is little voltage across the relay coil and one diode drop across Q1's base-emitter junction (~0.6V).

The 10MΩ/3.3MΩ feedback voltage divider across the comparators means that when the capacitor is charged beyond 15.8V (ie, its bottom end goes below -3.8V), the voltage at the comparator non-inverting inputs drops below 0V.

We confirm this by performing the calculation for this voltage divider, ie, (-3.8V x 10MΩ + 11.4V x 3.3MΩ) ÷ 13.3MΩ = -0.03V.

The inverting inputs, pins 8 and 10, are connected to ground so once the capacitor has sufficient charge, the outputs of IC1c and IC1d go low and pull the base of PNP transistor Q1 to -12V. Q1 is an emitter follower and so in this case, it sinks current through the coil of RELAY1, turning it on.

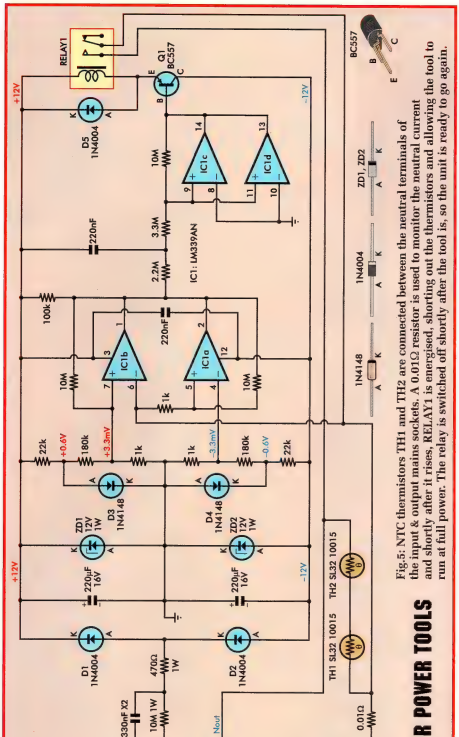


Fig.5: NTC thermistors TH1 and TH2 are connected between the neutral terminals of the input & output mains sockets. A 0.01Ω resistor is used to monitor the neutral current and shortly after it rises, RELAY1 is energised, shorting out the thermistors and allowing the tool to run at full power. The relay is switched off shortly after the tool is, so the unit is ready to go again.

The voltage at the non-inverting inputs them becomes (-3.8V x 10MΩ + -12V x 3.3MΩ) ÷ 13.3MΩ = -5.8V. This is the hysteresis for this stage and the capacitor must discharge by this additional amount before the relay turns off.

This allows the relay to stay on through brief dips in the load current. Diode D5 protects transistor Q1 from any voltage spike created when the relay turns off.

Power supply

The ±12V rails are derived from the mains Active line via a 330nF X2 series capacitor, 470Ω current-limiting resistor and dual half-wave rectifier formed by diodes D1 & D2. These diodes charge the 220µF capacitors alternately with each mains half-cycle, to provide the positive and negative rails. 12V zener diodes ZD1 and ZD2 limit the voltage across these capacitors to about 11.5V. The 330nF capacitor and 470Ω resistor limit the current and thus dissipation in ZD1 and ZD2 to well below their rated 1W.

If you ignore the X2 capacitor and two 1W resistors, this is a traditional AC-to-DC voltage doubler supply. The X2 capacitor has an impedance at 50Hz of around 9.65kΩ which limits the mains current to about 230V ÷ 9.65kΩ = 24mA. It's a bit more complicated than this calculation implies but that's a reasonable approximation.

We could have used a wirewound resistor of a similar value but it would then dissipate $0.024A^2$ x 9.65kΩ = 5.5W. The capacitor dissipates virtually no power.

The parallel 10MΩ resistor discharges the X2 capacitor once power is removed while the 470Ω series resistor limits the inrush current when power is first applied.

For more details on how this type of supply works, see the description in the original Soft Starter article (April 2012).

The specified relay has a nominal coil resistance of 1.1kΩ. This means with a 24V supply it will draw around 22mA. As stated earlier, the X2 capacitor limits the supply current to about 24mA; less due to the series 470Ω resistor and other factors.

When the relay is turned on, the X2 capacitor and 470Ω resistor form a voltage divider with the coil resistance. The supply rails then drop to about ±6V and the two zener diodes cease

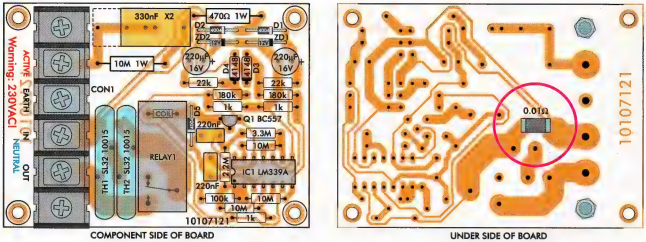


Fig.6: use these overlay diagrams and the photograph below as a guide when building the Soft Starter. Just one component, the 0.01Ω SMD resistor, goes on the underside. The diodes, electrolytic capacitors and IC1 must be installed with the orientations shown here. Multiple pads are provided to suit differently sized X2 capacitors. Secure CON1 with a machine screw at each end before soldering its pins.

conducting, since most of the input current flows through the relay coil.

The relay gets close to the full 24V across its coil initially to turn it on but the 220µF capacitors then partially discharge. The reduced coil voltage is sufficient to keep it energised and the rest of the circuit will run happily with ±6V or less. When the relay turns off, the 220µF capacitors charge back up to their original level.

PCB layout

While various components in the circuit are shown connected to ground, the main reference point is the "Nin" (Neutral In) terminal of CON1. This is the potential which the shunt sense voltage is relative to. Because this is very low (just a few mV), it's critical that the ±3.3mV references track this ground potential accurately or the unit won't work properly.

Therefore, the connection between the cathode of D3, the anode of D4 and pin 3 of CON1 is separate from other ground paths.

This way, current flowing through ZD1, ZD2, the 220µF capacitors and other components to ground does not interfere with the comparator's operation.

As is typical with a circuit which runs directly from mains, the PCB has a high voltage section at 230VAC and a low voltage section of ±12V (relative to the neutral potential).

Since the only components connected to active are the 10MΩ 1W resistor and 330nF X2 capacitor, all other tracks are clear of those pins. There can also be a fairly high voltage across TH1 and TH2 when they are conducting so their terminals are kept clear of other tracks.

Construction

The Soft Starter for Power Tools is built on a PCB coded 10107121, measuring 59 x 80.5mm. It is a double-sided PCB with tracks on the top side, paralleling the high-current paths on the bottom to improve its current-handling capability. All components

Here's a view inside the box, fairly close to life-size. You can clearly see the way the wiring is connected to the terminal block on the left end of the PCB – follow this along with the diagram above when wiring it up. If placed inside a metal box, the earth wires must instead be firmly anchored to the box – see text for more details.

Parts list – Power Tool Soft Starter

1 PCB, code 10107121, 59 x 80.5mm (available from Silicon Chip for $10 + P&P)
1 6-position, 4-way PCB-mount terminal barrier (CON1) (Jaycar HM3162, Altronics P2103)
2 Ametherm SL32 10015 NTC thermistors (Element14 1653459)
1 250VAC 16A SPST relay, 24V DC coil (Element14 1891740 or similar)
1 UB3 jiffy box ***or*** 1 diecast IP65 aluminium case (eg, Jaycar HB5046)
4 tapped M3 spacers, 5-6mm long (*required only for diecast case*)
4 M3 x 15mm Nylon machine screws
4 M3 nuts
4 M3 shakeproof washers
1 chassis-mount M205 safety fuse holder
1 10A M205 fuse
2 M3 x 15mm machine screws and nuts (*to attach terminal block to PCB*)
2 cord-grip grommets to suit 7.4-8.2mm cable (Jaycar HP0716, Altronics H4270)
1 100mm length brown mains-rated heavy duty (10A) insulated wire
1 50mm length 2.5mm diameter heatshrink tubing
1 short (~1m or so) 10A mains extension cord

Semiconductors

1 LM339A quad precision comparator (IC1) (*do not substitute LM339*) (Element14 9755969)
1 BC557 100mA PNP transistor (Q1)
2 12V 1W zener diodes (ZD1, ZD2)
3 1N4004 1A diodes (D1, D2, D5)
2 1N4148 small signal diodes (D4, D4)

Capacitors

2 220µF 16V PCB-mount electrolytics
1 330nF X2 capacitor (Element14 1200831)
2 220nF MKT

Resistors (0.25W, 5% unless otherwise stated)

3 10MΩ	1 3.3MΩ	1 2.2MΩ	2 180kΩ
1 100kΩ	2 22kΩ	3 1kΩ	
1 10MΩ **1W**	1 470Ω **1W**		

1 10mΩ 2W/3W SMD resistor, 6331/2512 package (Element14 1100058) (*NB: that is 10 milliohms, not 10 Megohms!)*

are through-hole types which mount on the top with the exception of the 10mΩ resistor which is an SMD.

Refer to the overlay diagram, Fig.6. Start by soldering the chip resistor in place. First, add some solder to one of its two pads using a hot iron. Place the resistor near the pads with its labelled side up, then heat the solder and slide it into place. Remove the iron and check that it is centred over its pads. If not, re-heat the solder and nudge it again.

Once it's in the correct position, solder the other pad. Add a little extra solder to the first one, to re-flow it and ensure a good joint.

You can then fit the smaller through-hole resistors, checking each value with a DMM to ensure they go in the right locations. Follow with the seven diodes, orientating them as shown on the overlay diagram. There are three different types; use the overlay diagram as a guide to which goes where (if you mix them up it won't work!).

Fit the two 1W resistors next, then solder IC1 in place. While used a socket on our prototype (for development reasons) you shouldn't. Ensure IC1's pin 1 notch or dot goes towards the bottom left as shown in the overlay diagram. You can then mount Q1, bending its leads with small pliers to suit the pad spacings. Its flat face is orientated as shown.

The two MKT capacitors go in next, followed by the electrolytic capacitors, with their longer (positive) leads through the holes marked "+".

There are multiple pads to suit different sized X2 capacitors; solder it in place with one pin in the right-most position and the other through the appropriate left-hand hole.

Now you can fit the relay and thermistors (pushed as far down as they will go). Attach the terminal barrier using the 15mm M3 machine screws, with a star washer under each head and nut. Do them up tight, make sure it's straight and then solder the four pins. The PCB assembly is then complete.

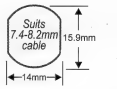


Fig.7: the correct cut-out to make sure cord-grip grommets do grip! Don't be tempted to simply drill a 16mm hole!

Housing

We housed our prototype in a UB3 jiffy box, which the PCB is designed to fit in. It is pushed down to the bottom of the box, so the taller components will clear the lid.

Even though it is a tight fit, to ensure it cannot move around it is fixed to the bottom of the box using Nylon screws (the nuts inside can be Nylon or metal).

If this unit is to be used on construction sites or in other rough situations where it's likely to be knocked around a bit, it should be housed in a larger, sturdier ABS plastic or (preferably) a diecast aluminium case.

If you want to do this, fit four tapped spacers to the mounting holes on the PCB and then drill four corresponding holes in the box. If the box is plastic, be sure to use Nylon spacers and screws (metal is OK on the inside) so that you don't breech the insulation barrier.

If you use a diecast aluminium box, the two mains earth wires must have crimp eyelet connectors fitted (use a ratcheting crimping tool), both terminated on a machine screw through the case which is fitted with star washers and two nuts. This earths the case so that an internal wiring fault can't create a lethal situation.

Whichever housing you use, the first step is to drill three holes; two 14mm holes for the cordgrip grommets which the mains cables pass through and one 11-12mm hole for the chassis-mount fuse holder. The fuse holder can go alongside the entry for the mains supply lead.

Use needle files to expand the grommet holes to the correct profile (see Fig.7). The requirements for fuse holders varies but they also often require the hole to be profiled; refer to the supplier or manufacturer data for the correct shape.

Solder a short length of brown mains-rated wire to one of the fuseholder terminals and heatshrink the joint. Fit the fuseholder to the box and position the completed PCB inside it. You can then cut the extension cord in half and strip a 50mm length of the outer insulation from both free ends. Also strip back 6-8mm of insulation from each of the three inner wires of the two cables.

Feed the cables through cordgrip grommets, squeeze the grommet halves together and push them into place through the holes you made earlier.

If you are lucky enough to have a tool for inserting cordgrip grommets use that, otherwise some sturdy pliers will do. The grommets are hard to take out once they're in so check that you have fed through an appropriate length of cable so that the individual wires will reach the terminals on the PCB. Keep in mind that the brown (active) wire from the plug end of the cable must reach the fuseholder.

Slip some heatshrink tubing over that Active wire (plug end) and solder it to the free tab on the fuseholder. Slip the tubing down and shrink it over the joint. Secure the five remaining wires into the PCB terminal barrier as shown in the photo on page 27.

Make sure there are no stray copper strands and that the terminal screws are done up very tightly so nothing can come loose.

As mentioned earlier, if you are using a metal box (eg, diecast aluminium) you will need to make the earth connections to a chassis earth point rather than on the PCB.

Testing

Because the X2 capacitor limits the circuit current, it can be quite safely tested from mains – but don't put your fingers anywhere near the PCB.

Here's the complete project, ready to use. There are no controls on the box . . . because there are no controls! If used in a rough environment, we'd suggest a diecast box – even if a little larger (eg, Jaycar cat HB5046).

First, check your wiring. Then put the lid on the box and install a fuse. Use a DMM to check for continuity between the Earth terminals of the plug and socket. The resistance must be low (<1Ω).

Do the same check with the two Active terminals and two Neutrals. The resistance between the two Actives should also be low (<1Ω) while between the two Neutrals should be around 20-30Ω (the cold resistance of the NTC thermistors).

Also measure the resistance between each combination of Active, Earth and Neutral on each plug. You should get >10MΩ resistance between Earth/Neutral and Earth/Active at both plug and socket. The resistance between Active and Neutral should be around 10MΩ at each end (it may read lower initially due to the capacitors charging).

Connect a 100W or greater 230V lamp (eg, a portable PAR38 floodlight – incandescent, not LED!) to the output socket. While keeping your eye on the lamp, plug the power cord into the wall outlet and switch it on.

Check that the lamp switches on properly – for all intents and purposes, it should appear pretty normal in brightness.

But about one second after this, you should hear the relay click and the lamp will get slightly brighter. Switch the lamp off and check that the relay clicks off after about a second.

If it doesn't work, switch off at the wall, unplug both ends, open the box and remove the PCB. Check for components which are swapped or incorrectly orientated. If you don't see any component problems, check the solder joints and ensure that there are no breaks or short circuits between the tracks or pads.

(Kit suppliers tell us that around 50% of problems with kits are mistakes in component placement. Most other problems are bad solder joints [or components not soldered in!]).

Assuming all is well, you can then do a full test with a power tool to check that it is working as expected.

Remember that if you start the tool multiple times in quick succession, the second and later starts will not have as effective current limiting due to the thermistors heating up. SC

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	4[a]	10MΩ	brown black blue brown	brown black black green brown
☐	1	3.3MΩ	orange orange green brown	orange orange black yellow brown
☐	1	2.2MΩ	red red green brown	red red black yellow brown
☐	2	180kΩ	brown grey yellow brown	brown grey black orange brown
☐	1	100kΩ	brown black yellow brown	brown black black orange brown
☐	2	22kΩ	red red orange brown	red red black red brown
☐	3	1kΩ	brown black red brown	brown black black brown brown
☐	1[b]	470Ω	yellow violet brown brown	yellow violet black black brown

[a] 1 of the 10MΩ is 1W [b]1W

Capacitor Codes

Value	μF Value	IEC Code	EIA Code
330nF*	0.33μF	330n	334
220nF	0.22μF	220n	224

* must be X2 type

Pt.2: By JOHN CLARKE

Wideband Oxygen Sensor Controller Mk.2

Last month, we introduced our new Wideband Oxygen Sensor Controller Mk.2 and described the circuit. This month, we give the circuit for the display unit and the full construction details.

WHILE A VOLTMETER could be used to monitor the Wideband Controller's 0-5V output, the measured voltage does not directly indicate the lambda value. Instead, you would need to use the equation **lambda = [V x 0.228 + 0.70]** to convert the controller's wideband output voltage (V) to the corresponding lambda value.

That's where the Wideband Oxygen Sensor Display comes in. It plugs directly into the controller unit and automatically calculates and displays the correct lambda value. What's more, the Wideband Oxygen Sensor Display is set up to give the correct 0.70-1.84 lambda range by default, so you do not have to make any adjustments during construction.

Alternatively, you can alter the display to show the air-fuel ratio or you can program the unit to monitor any other signal source over a 0-5V range and display a corresponding readout (see panel).

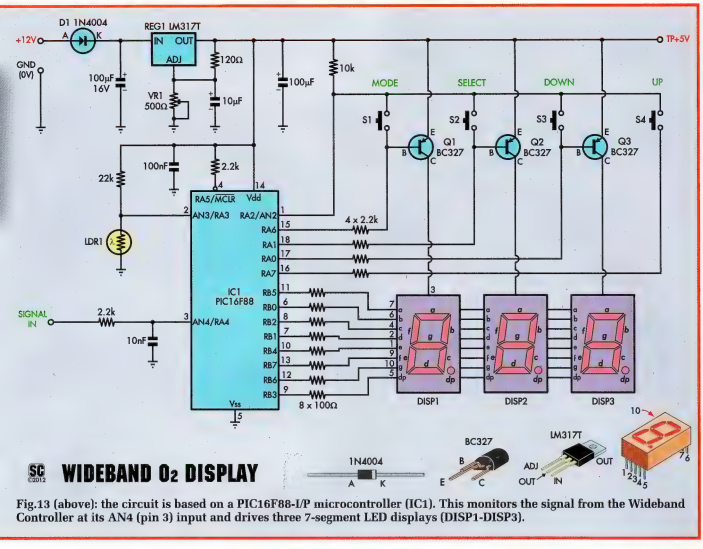
As shown in the photos, the display unit is built into a small plastic case and this measures 83 x 54 x 31mm. Three 7-segment LED readouts are used to display the reading and these are visible through a red Perspex or acrylic window that takes the place of the original box lid. A single cable fitted with a 3.5mm stereo jack plug connects the unit to the wideband output on the controller and this carries both the signal and power (12V).

The unit itself consists of a PIC16F88-I/P microcontroller, three 7-segment displays, a 3-terminal regulator and not much else. It features display dimming in low ambient light (so it's not too bright at night), while four micro tactile switches allow the displayed values to be adjusted during set-up (if necessary).

Circuit details

Take a look now at Fig.13 for the circuit details of the Wideband Oxygen Sensor Display. It's built around PIC microcontroller IC1, with most of the complexity hidden inside its software program.

IC1 monitors the signal from the Wideband Controller, processes the data and drives the three 7-segment LED displays to show the calculated lambda value (or the air-fuel ratio if preferred). Output ports RB0-RB7 drive the display segment cathodes, while PNP transistors Q1-Q3 (BC327)



SC 2012 **WIDEBAND O_2 DISPLAY**

Fig.13 (above): the circuit is based on a PIC16F88-I/P microcontroller (IC1). This monitors the signal from the Wideband Controller at its AN4 (pin 3) input and drives three 7-segment LED displays (DISP1-DISP3).

switch the common display anodes, so that only one display digit is driven at any given time (ie, the displays are multiplexed).

Note that the cathode segments common to each display are tied together. For example, the "a" segment of DISP1 connects to the "a" segments of DISP2 and DISP3. These "a" segments are driven from the RB5 output of IC1 via a 100Ω resistor. As a result, when this output is low, the "a" segment in one display will light, depending on which digit driver transistor is turned on.

Transistors Q1-Q3 are driven by ports RA6, RA1 & RA0 via 2.2kΩ resistors. For example, transistor Q1 is controlled by RA6 and when this output is high, Q1 is held off. Conversely, when RA1 goes low (0V), Q1's base is pulled low and so Q1 turns on. As a result, any segments within DISP1 that have their cathodes pulled low via IC1's RB outputs (and their respective 100Ω resistors) would then light.

Transistors Q2 and Q3 are driven in a similar manner to Q1 to control 7-segment displays DISP2 and DISP3. This on-off switching of the displays is done at such a fast rate (around 2kHz) that the displays all appear to be continuously lit, even though only

Display Unit Features & Specifications

Features

- 3-digit LED display
- Preset display range of 0.70 to 1.84 lambda
- 0-5V input range & linear display ranging
- Adjustable 0V and 5V endpoint values
- Decimal point positioning adjustable
- Automatic leading zero suppression
- Display dimming with minimum brightness adjustment
- Quieting period used for input measurement to ensure accuracy

Specifications

- Power supply: 6-15V @ 240mA
- Input current loading: less than 1µA
- Digit update period: 250ms
- Wideband display reading range: 0-999

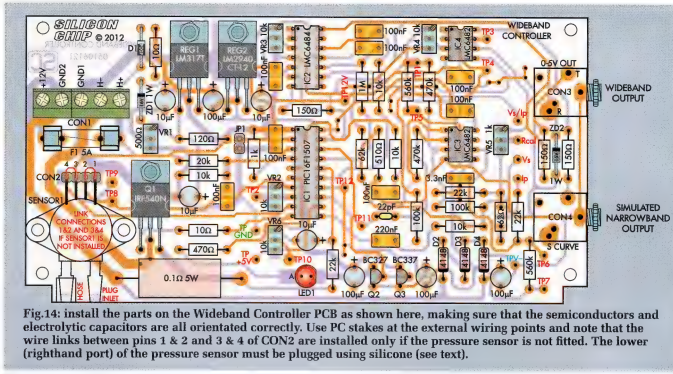


Fig.14: install the parts on the Wideband Controller PCB as shown here, making sure that the semiconductors and electrolytic capacitors are all orientated correctly. Use PC stakes at the external wiring points and note that the wire links between pins 1 & 2 and 3 & 4 of CON2 are installed only if the pressure sensor is not fitted. The lower (righthand port) of the pressure sensor must be plugged using silicone (see text).

one transistor is on at any time, ie, first Q1, then Q2 and then Q3.

The RA7 output is used to monitor pushbutton switch S4. This output is momentarily taken low after transistor Q3 is switched off and before Q1 is switched on again (more about this later).

Display dimming

Light dependent resistor LDR1 is used to sense the ambient light to control the display dimming. This is connected in series with a 22kΩ resistor to form a voltage divider across the +5V rail and its output is fed to IC1's AN3 input.

When the ambient light level is high, the LDR has a low resistance and the voltage at the AN3 input is pulled down close to 0V. Conversely, in low ambient light, the LDR has a high resistance and the AN3 input is pulled close to the +5V rail via the 22kΩ resistor. And at intermediate light levels, the voltage on AN3 will sit somewhere between 0V and +5V.

Microcontroller IC1 dims the displays in response to its AN3 voltage. That's done by limiting the amount of time that the displays are lit. In bright light, each display is lit for almost 25% of the total time but this reduces as the voltage on AN3 rises in response to falling light levels.

In fact, at very low light levels, each display might only be lit for about 2% of the time.

Pushbutton switches

Switches S1-S4 allow the unit to be programmed by providing the Mode, Select, Down & Up functions. These switches are commoned on one side and connected to the +5V rail via a single 10kΩ resistor. They are also connected to IC1's AN2 input and this monitors the switches as described below.

The other sides of switches S1-S3 are connected respectively to the bases of transistors Q1-Q3, while S4 connects to the RA7 output via a 2.2kΩ resistor (as mentioned previously). If S1-S4 are all open, IC1's AN2 input will be held at +5V via the 10kΩ pull-up resistor. However, if a switch is closed, AN2 will either be connected to the base of the corresponding transistor or to RA7 via the 2.2kΩ resistor.

As a result, if one of switches S1-S3 is pressed, the voltage on AN2 will drop to about 0.6V below the +5V rail (ie, to 4.4V) when the corresponding transistor switches on. Alternatively, if S4 is pressed, the AN2 voltage will drop to about 900mV each time the RA7 output goes low, due to the voltage divider action of the 10kΩ resistor to the +5V rail and the 2.2kΩ resistor in series with RA7.

In operation, the microcontroller periodically checks the voltage at its AN2 input. As a result, it can decide if a switch has been closed based on the AN2 voltage and then determine which switch it is by checking which transistor is currently switched on or if RA7 is low.

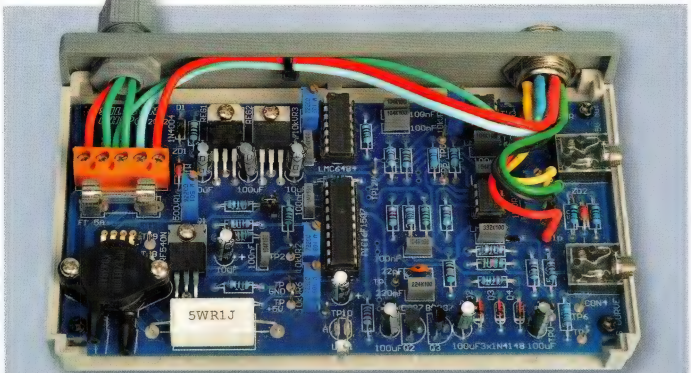
Input signal

The input signal from the Wideband Controller is fed to the AN4 pin of IC1 via a 2.2kΩ current-limiting resistor and filtered using a 10nF capacitor. IC1 converts this input voltage into a 10-bit digital value which is then processed by the software and the resulting calculated value fed to the LED displays.

The 2.2kΩ input resistor and internal clamping diodes inside IC1 protect the AN4 port if the input goes above the +5V supply or below the 0V rail; ie, out-of-range input voltages are clamped to the supply rails. The 10nF capacitor filters any voltage spikes that may be applied to the input.

A feature of unit is that it switches off all the displays for a short period before measuring the input voltage. This minimises any voltage drops that could occur due to supply current flowing in the ground wiring if the displays were lit and ensures accurate measurements.

Timing for IC1 comes from an internal oscillator running at 4MHz. This



This view shows the fully-assembled Wideband Controller, with all wiring completed. Fit heatshrink over all wiring connections to the PCB and the 8-pin panel plug to prevent shorts. Note that the ICs should be left out of their sockets until after some initial tests have been completed (see text).

has an accuracy of about 2% which is close enough for this application, as the timing is not critical.

Power supply

Power (ie, 12V) is derived from the Wideband Controller via reverse polarity protection diode D1 and fed to an adjustable 3-terminal regulator (REG1). The 100µF capacitors across REG1's input and output terminals provide bypassing, while the 10µF capacitor at the adjust (ADJ) terminal reduces the output ripple.

Trimpot VR1 sets the output voltage and is adjusted to produce a + 5V rail.

In works like this: REG1 has a 1.25V reference between its OUT and ADJ terminals and so a current of 10.4mA flows through the associated 120Ω resistor. This current also flows through VR1. If VR1 is adjusted to 360Ω, it will have 3.75V across it and the output voltage from REG1 will be 3.75 + 1.25V = 5V.

Note that, in practice, the 1.25V reference can be anywhere between 1.2V and 1.3V, which is why we need to adjust the output using VR1.

The supply rail to IC1 is further decoupled using a 100nF capacitor at pin 14. In addition, a 2.2kΩ resistor between IC1's MCLR input (pin 4) and the +5V rail provides the power-on reset signal for IC1.

Building the controller

OK, let's now build the Wideband Controller unit. It's quite straightforward to assemble, with all parts (except for the wideband oxygen sensor) mounted on a PCB coded 05106121 and measuring 149 x 76mm. This is housed in an ABS box measuring 155 x 90 x 28mm.

An 8-pin circular multi-pole panel plug connector is used to provide the interface to the external wideband sensor. This sensor is mounted on the exhaust (either directly or via an adaptor pipe) and connects to the controller via a 7-way extension cable.

A separate cable enters through a cable gland at the other end of the box and this supplies power to the controller PCB. The wires in this 3-way cable terminate to an on-board screw terminal block. The wideband and narrowband outputs are fed out on one side of the case via 3.5mm stereo jack sockets.

Fig.14 shows the parts layout on the PCB. Begin by checking the board for any defects such as shorted tracks or breaks in the copper. Check also that the corners have been shaped to clear the internal moulding of the box by test-fitting it in place.

Note that the box comprises a base and a lid (as well as front and rear panels) and each is clearly labelled on the inside surface. The PCB mounts onto the base.

Once these checks are complete, start the PCB assembly by installing the resistors. Table 1 shows the resistor colour codes but you should also check each one using a digital multimeter before soldering it in place. The 0.1Ω 5W resistor runs cold and can be mounted flush against the PCB.

Next, install the diodes, zener diodes and the IC sockets. Make sure that each socket is orientated correctly (ie, with its notched end towards the top of the PCB). Follow with the capacitors, taking care to install the electrolytic types with the polarity indicated.

That done, install REG1, REG2 and Q1. These parts are all mounted flat against the PCB, so you will have to bend their leads down through 90° to get them to fit. This involves bending the two outer leads of each device down about 8mm from its body, while the middle lead is bent down about 6mm away.

Secure each device to the PCB using an M3 x 10mm screw and nut before

The front side panel has a hole drilled at the lefthand end so that a plastic hose can be run to the upper port of the pressure sensor. The status LED fits through a 3mm hole in the centre of this panel.

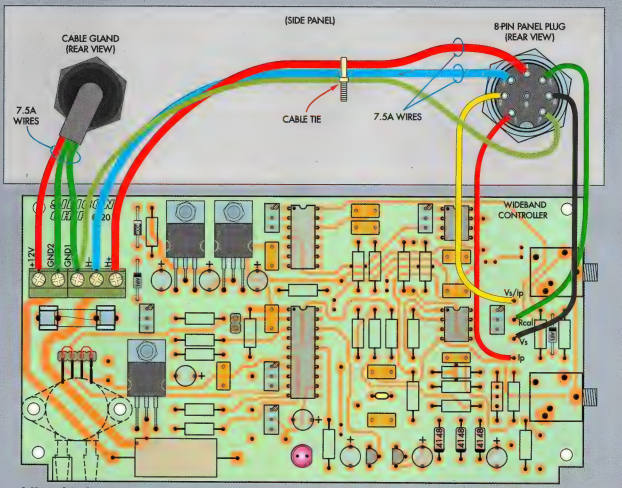


Fig.15: follow this diagram to complete the external wiring. Be sure to use 7.5A cables where indicated and note that two power supply earth leads are run out through the cable gland at left and secured to the vehicle's chassis near the battery earth point (the second earth lead is necessary to handle the heater current).

soldering its leads. Make sure that each device goes in the correct location.

Transistors Q2 and Q3 can go in next. Be sure to use a BC327 for Q2 and a BC337 for Q3 (do not get them mixed up). Once they're in, install the 2-way pin header for JP1 (below REG2), then install PC stakes at the test points and external wiring positions.

LED1 is next on the list. This is installed by first orientating the LED as shown in Fig.14 (anode to the left) and bending its leads down at right angles about 8mm away from its body. That done, the LED is mounted in position with its leads some 6mm above the board surface. A 6mm spacer will make it easy to set the height correctly.

The six trimpots (VR1-VR6) can now go in. Check that the correct value is installed at each location and orientate each one with its adjusting screw as shown on Fig.14 (this ensures that the voltages at their wipers increase with

Table 1: Wideband Controller Resistor Colour Codes

No.	Value	4-Band Code (1%)	5-Band Code (1%)
1	1MΩ	brown black green brown	brown black black yellow brown
2	560kΩ	green blue yellow brown	green blue black orange brown
2	470kΩ	yellow violet yellow brown	yellow violet black orange brown
2	100kΩ	brown black yellow brown	brown black black orange brown
1	62kΩ	blue red orange brown	blue red black red brown
3	22kΩ	red red orange brown	red red black red brown
1	20kΩ	red black orange brown	red black black red brown
4	10kΩ	brown black orange brown	brown black black red brown
1	1kΩ	brown black red brown	brown black black brown brown
1	500Ω	green black brown brown	green black black black brown
1	470Ω	yellow violet brown brown	yellow violet black black brown
3	150Ω	brown green brown brown	brown green black black brown
1	120Ω	brown red brown brown	brown red black black brown
1	62Ω	blue red black brown	blue red black gold brown
2	10Ω	brown black black brown	brown black black gold brown
1	0.1Ω 5W	not applicable	not applicable

clockwise rotation). Note that these trimpots may be marked with a code other than the actual resistance value in ohms, ie, the 500Ω trimpot may be coded as 501, the 10kΩ trimpots may be coded as 103 and the 1kΩ trimpot may be coded as 102.

The 3-way and 2-way screw terminal blocks that comprise CON1 can now be installed. These must be dovetailed together to form a 5-way block before soldering them in position (the wiring access holes must face towards the rear of the PCB). The fuse clips can then be installed, taking care to ensure that the stopper flange on each clip goes to the outside (otherwise you won't be able to insert the fuse later on).

Follow these parts with the 3.5mm stereo sockets (CON2 and CON3). Check that these sockets are seated flush against the PCB before soldering their leads.

Finally, complete the PCB assembly by installing the pressure sensor (Sensor1). This is installed by bending its leads down through 90° and plugging it into a 4-way socket strip (CON2).

Solder the socket strip to the PCB first, then carefully examine the pressure sensor. This has a small notch in its pin 1 lead and this must go to the right. Once you've got its orientation sorted out, bend its leads down and plug it into the socket strip. The sensor can then be secured to the PCB using two M3 x 15mm screws and nuts.

Note that the pressure sensor is optional (although it should be installed if you wish to compensate for exhaust manifold pressure). If the sensor is not installed, then pins 1 & 2 of CON2 must be bridged. The same goes for pins 3 & 4. This is best done by bridging the solder connections on the underside of the PCB, or you can simply install wire links through the PCB in place of CON2.

Boxing it up

Once the PCB is finished, you're ready to install it in the ABS case. This case is opened up by unclipping the front and rear panels – just squeeze the top and bottom sections of the case at the positions indicated by the arrows and pull the panels off.

The PCB assembly is secured to the integral mounting bushes on the base. Before doing this though, you will need to file two half circles in the righthand side of the case to provide clearance for the threaded collars of the stereo jack sockets. This can be done using a small rat-tail file.

Similarly, the matching side of the lid must also be filed to complete the

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
220nF	0.22µF	220n	224
100nF	0.1µF	100n	104
3.3nF	.0033µF	3n3	332
1nF	.001µF	1n	102
22pF	NA	22p	22

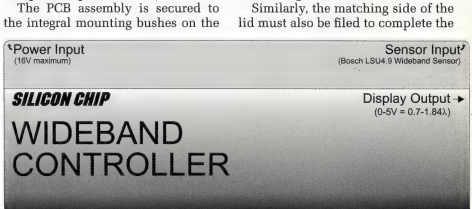


Fig.16: this full-size front panel for the Wideband Controller can either be copied or downloaded in PDF format from the SILICON CHIP website.

The two 3.5mm stereo jack sockets protrude through holes at one end of the case.

circular clearance holes required for the 3.5mm socket collars.

The front panel can now be drilled and reamed to provide the necessary holes for the LED and pressure sensor (if used). You will need to drill a 3mm hole right in the centre of the panel for the LED and a hole directly in front of the top port of the pressure sensor (about 11mm down from the top and 13mm in from the side). The diameter of this latter hole will depend on the diameter of the plastic tubing used but will be about 9mm.

On the rear panel, the cable gland and the circular connector are both positioned 19mm in from their respective ends. Both are centred vertically.

Once the holes are drilled and reamed to size, mount the gland and the connector in position. Note that the hexagonal nut that's used in each case must be orientated so that two of its flat sections are parallel to the top and bottom edges of the panel. If you don't do this, the nuts will interfere with the top and bottom case sections when you try to attach the panel.

Note also that some cable gland nuts have a moulded circular section behind the nut and this will need to be cut away so that its faces are flat.

Once all the holes have been drilled, secure the board in position using four M3 x 5mm screws, then run the wiring as shown in Fig.15. Note that you must use 7.5A rated wire for the 12V supply, ground and heater wires.

The 8-pin circular panel connector is wired by first connecting the sensor leads to the PC stakes on the PCB and the heater and earth leads to the screw terminal block. The free ends of these leads are then soldered to the connector itself.

Note that each soldered pin on the connector is covered with heatshrink tubing to avoid shorts and to prevent the leads from breaking. This means that you have to slide a length of heatshrink over each lead before soldering it to the connector. After soldering, the heatshrink is pushed over the connection and shrunk down with a hot-air gun.

The power supply leads must be fed through the cable gland before connecting them to the screw terminal block. Note that because of the currents involved in the heater circuit, two power supply earth wires must be used as shown in Fig.15. These connect together at the vehicle's chassis near the battery's negative lead while the +12V lead goes to the vehicle's battery via the switched ignition circuit.

Alternatively, for temporary use, the cigarette lighter socket can be used to provide power via a lighter plug connector.

Sensor extension cable

The sensor extension cable is made using a 6-way sheathed and shielded lead from TechEdge (see parts list last month). It's wired as shown in Fig.17. Make sure that the wiring is correct and be sure to use heavy duty (7.5A) leads in the cable for the H+ and H- leads.

The wiring is shown from the back (soldering side) of each connector, so be sure to follow Fig.17 carefully. Note that the 6-pin connector includes rubber sealing glands and these are placed over each lead before it is attached to the 2.8mm female crimp spade terminals.

Setting up

Before setting up the completed unit, first check that all the ICs are out of their sockets, that the sensor is unplugged and that there's no jumper plug for JP1. It's then simply a matter of following this step-by-step procedure:

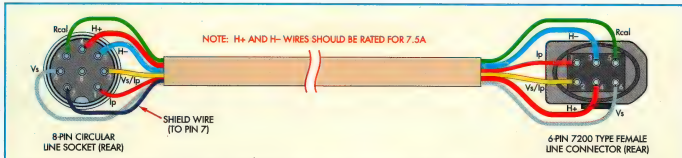
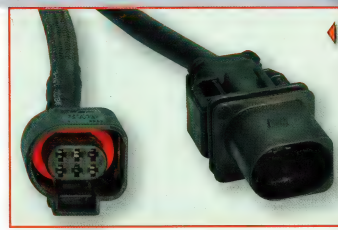


Fig.17: this diagram shows the wiring details for the sensor extension cable, with the socket connections shown from the rear. Make sure that the wiring is correct, otherwise the oxygen sensor could be damaged. Note that you must use heavy-duty cable for the heater H+ and H- leads.

Above: the completed extension cable with the oxygen sensor attached. The sheathed lead that's used to make the extension cable is available from TechEdge – see parts list last month.



This view shows the female 6-pin connector (left) at the end of the extension cable and the matching male plug that comes fitted to the sensor (right).

Step 1: connect a multimeter between TP3 and Rcal, set the meter to read ohms and adjust trimpot VR5 for a reading of 311Ω.

Step 2: Apply power (12V) to the circuit, monitor the voltage between TP +5V and TP GND and adjust VR1 for a reading of 5.00V.

Step 3: Connect the multimeter between TP GND and TP2 and adjust VR2 for 4V. This initially sets the engine-started battery voltage detection at 12V.

Step 4: Switch off, install IC2, IC3 & IC4 (but not IC1) and apply power again. Monitor the voltage between TP1 and TP GND and adjust VR3 for a reading of 3.3V, then monitor the voltage between TP4 and TP GND and adjust VR4 for a reading of 3.92V.

Step 5: Switch off and install IC1 in its socket (watch its orientation). Reapply power and check that TP12V is at about 12V (note: it will be slightly lower than 12V if the supply is only 12V).

Step 6: Check that the voltage at TPV- is close to -2.5V. If the latter voltage is positive, check the orientation of diodes D2-D4 and check the placement of Q2 & Q3. Check the orientation of the 100µF capacitors as well.

Step 7: With the sensor still un-

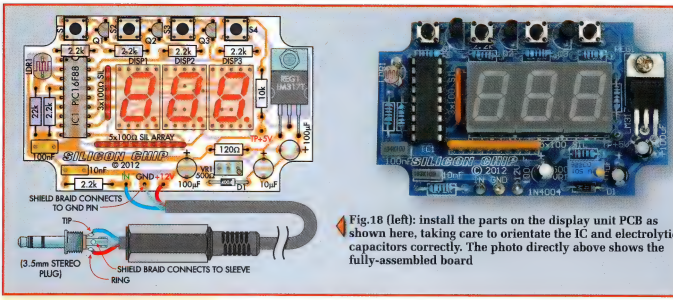


Fig.18 (left): install the parts on the display unit PCB as shown here, taking care to orientate the IC and electrolytic capacitors correctly. The photo directly above shows the fully-assembled board

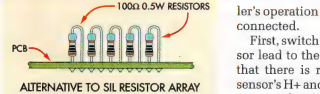


Fig.19: if you are unable to obtain the resistor arrays, separate 100Ω resistors can be used instead. These are mounted end-on, as shown here.

plugged, check that the status LED is initially at low brightness when power is applied. Check that it then goes to full brightness for 4s and then flashes at a 1s rate, indicating an error with the sensor connection.

Step 8: As mentioned in Pt.1, VR6 sets the pressure offset in the event that the pressure sensor is plugged at an altitude above sea level. Adjust this trimpot to set TP10 to 1V/1000m. For example, at 500m above sea level, adjust VR6 to set TP10 at 0.5V. At sea level, adjust VR6 for 0V on TP10.

Step 9: Once step 7 is completed, plug the hole in the pressure sensor's lower port with silicone sealant.

Testing with the O_2 sensor

The next step is to check the controller's operation with the oxygen sensor connected.

First, switch off and connect the sensor lead to the controller. Now check that there is resistance between the sensor's H+ and H- heater terminals, as measured at the screw terminal block. You should get a reading of about 3.2Ω at 20°C.

When power is subsequently applied, the sensor will become hot, so be sure to first remove the plastic protective cap. In addition, the sensor should be placed on a surface that can withstand 200°C. Glass cookware (eg, Pyrex) is ideal but do not hit the sensor against the glass, otherwise its ceramic element could crack.

It's also important to note that the tip of the sensor can become hot enough to burn skin when power is applied.

You will need a 12V supply that can deliver about 2A. Apply power and check that LED1 lights dimly for 2s, then goes to full brightness for around 10s before flashing at a 1s rate. The slow (1s) flashing means that the sensor is measuring a lean mixture beyond its range. That's because it's sitting in open air with 21.9% oxygen rather than monitoring a burnt fuel mixture.

You can further check the controller's operation by setting it up for an oxygen measurement, to be described in Pt.3 next month. Additional tests can also be carried out after the oxygen sensor is fitted to a vehicle, to measure the exhaust.

If the controller doesn't appear to be operating correctly, check for assembly errors and repeat the setting-up procedure.

Having completed the above tests, adjust VR2 so that TP2 is at 4.33V. This sets the controller to wait until the supply voltage reaches 13V (ie, after the engine has started) before beginning to heat the sensor.

Building the display unit

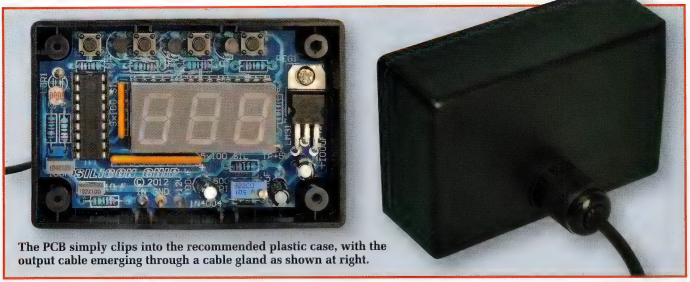
Fig.18 shows the assembly details for the display unit. All parts are installed on a double-sided PCB with plated-through holes and coded 05106122 (80 x 50mm). The completed assembly is housed in a small plastic case measuring 83 x 54 x 31mm.

Table 4: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
100nF	0.1µF	100n	104
10nF	0.01µF	10n	103

Table 3: Display Unit Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	22kΩ	red red orange brown	red red black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	6	2.2kΩ	red red red brown	red red black brown brown
❑	1	120Ω	brown red brown brown	brown red black black brown



The PCB simply clips into the recommended plastic case, with the output cable emerging through a cable gland as shown at right.

Begin by checking the board for any defects and by checking the hole sizes for the major parts. Check also that the PCB is cut and shaped to size so that it clips into the integral side slots in the case.

Install diode D1 and the resistors first, taking care to place each in its correct position. Table 3 shows the colour code values but you should also use a digital multimeter to check each resistor before installing it.

Note that the 100Ω resistors are in a single in-line (SIL) resistor array. Alternatively, you can use standard 100Ω 0.25W resistors here and these are installed by mounting them end-on as shown in Fig.19.

Next, install PC stakes at the test point and external wiring points. The TP+5V PC stake is installed from the top of the PCB while the IN, GND and +12V PC stakes go in on the underside of the PCB (the external wiring connects to the rear of the board).

Transistors Q1-Q3 are next on the list. These must be installed so that their tops are no higher than 12mm above the PCB. Once they're in, install the four switches (S1-S4). These switches can only go in with the correct orientation so if the holes don't line up, simply rotate them by 90°.

Regulator REG1 can now go in. This device mounts horizontally on the PCB, with its leads cranked down through 90° so that they pass through their corresponding holes. Secure its tab to the board using an M3 x 10mm screw and nut before soldering its leads (don't solder the leads first, otherwise the PCB tracks can crack as the mounting screw is tightened down).

Now install the capacitors. Take care to orientate the electrolytics as shown on the layout and note that these need to be no higher than 12mm above the PCB.

Mounting the displays

Now for the 7-segment LED displays. These are mounted by plugging them into a cut-down DIL40 IC socket, to raise them off the PCB.

The first step is to cut off a 2 x 5-pin section from one end of the IC socket using side cutters, a hacksaw or a sharp knife, so that 15 socket pins remain on each side. That done, the socket can be installed on the PCB and the displays inserted, making sure that the decimal points are at bottom right.

IC1 is mounted via an 18-pin DIL socket. Be sure to orientate this socket with its notched end towards the top before soldering its pins. Do not plug IC1 in yet, though – that step comes later.

The PCB assembly can now be completed by installing trimpot VR1 and then the LDR. The latter should be installed so that its top surface is exactly 15mm above the top of the PCB.

Testing

Once the assembly is complete, go over the board carefully and check for incorrect parts placement and for missed or shorted solder joints. If this all checks out, check that IC1 is out of its socket, then apply power to the +12V and GND (0V) terminals.

Next, connect a multimeter set to measure volts between the TP+5V test point and GND. Adjust VR1 for a reading of 5V on the meter, then disconnect power and install IC1.

When power is now reapplied you should be greeted with a display on the 7-segment digits. If not, check the orientation of IC1. If that's correct, check that transistors Q1-Q3 are BC327 PNP types.

Final assembly

The PCB is designed to simply clip into the specified plastic case. As mentioned earlier, the lid supplied with the case is discarded and replaced by a transparent red Perspex lid measuring 82 x 54 x 3mm. This not only allows the displays to be seen but also allows the LDR to receive ambient light to control the display dimming.

You will need to drill four corner holes in this lid and this can be done using the old lid as a marking template. **Note that the new lid sits on the top of the base; ie, it doesn't fit inside the case and rest on the corner pillars.** This is necessary to provide sufficient clearance for the 7-segment displays.

Before installing the PCB, you will need to drill a hole in the rear of the case and fit a cable gland. This hole is positioned towards the bottom of the box and is centred horizontally (see photo).

Twin-shielded wire (ie, two wires with a common shield) is used for the signal input and power supply connections. As shown on Fig.18, the shield is connected to the GND PC stake on the display PCB, the red wire to the +12V terminal and the blue wire to the signal "IN" stake.

Once these connections have been made, push the cable through the cable gland and clip the PCB into position

Displaying The Air-Fuel Ratio Or Other Numbers

The Wideband Oxygen Sensor Display is quite a versatile unit and can be used in applications other than with the Wideband Controller. You can change the display to indicate whatever numbers you like at the start and end of the 0-5V input signal range. In addition, the position of the decimal point can be changed.

This means that if you prefer to display the air/fuel ratio instead of the lambda value, it's easy to set up the display unit accordingly. For example, you may wish to set the display to show air/fuel ratio values ranging from 10.3 to 27.1, corresponding to lambda values ranging from 0.70-1.84 for petrol (petrol has an air/fuel ratio of 14.7 at stoichiometric, ie, when lambda = 1).

In this case, it's simply a matter of setting the display unit's lower (0V) endpoint value to 10.3 (ie, 0.7 x 14.7) and the upper (5V) endpoint value to 27.1 (1.84 x 14.7). If you are using a fuel other than petrol, then you will have to re-calculate the end point values accordingly – eg, diesel typically has a stoichiometric air/fuel ratio of 14.5:1 (this can vary according to the fuel supplied), while LPG has a stoichiometric air/fuel ratio of 15.5:1 (see panel on p38 of the July 2012 issue).

Other uses

For other applications, all you have to do is program in the two endpoint values to customise the response. One endpoint value is what you want the display to show when 0V is applied to the input. The second endpoint value is the value that's to be displayed when 5V is applied to the input. The unit then provides a linear response for input values between these two extremes.

Note that you're not restricted to using a lower endpoint value at the 0V input end than at the 5V input end. It's quite OK for the endpoint (or display) value for 0V input to be higher than the display value for 5V input.

The maximum value that can be displayed is 999 and no negative sign is available.

inside the box. The cable gland can then be tightened to secure the cable in position.

The other end of the cable connects to a 3.5mm stereo jack plug. Connect the shield to the sleeve of the 3.5mm jack plug, the +12V wire (red) to the ring and the signal lead wire (blue) to the tip.

Display adjustments

As mentioned previously, the display unit is set up to display the required 0.70 to 1.84 lambda range when used with the Wideband Controller. Alternatively, if you want to change the display values (eg, to display air-fuel ratios instead), then this is done using switches S1-S4.

Switch S1 (Mode) is used to select the normal display mode or the settings mode. The normal display is automatically selected at power up and this is where display values are shown in response to an input voltage. Each time S1 is pressed it alternates between this normal display mode and the settings mode.

The settings mode allows changes to be made for decimal point positioning, the 0V endpoint (or display) value, the 5V endpoint value and the minimum dimming for the display in that order. Whenever the settings mode is selected with S1, the display initially shows the decimal point positioning, ie, it shows "dP" plus the selected decimal point position. The decimal point can then be moved from left to right using the Down (S3) or Up (S4) switches (note: the decimal point does not light for DISP3 since this is not necessary).

Switch S2 (Select) cycles the display through the settings. The first press shows the 0V value, ie, the value that's displayed for 0V input. You can change this value using the Up and Down switches. Pressing S2 again will show the 5V display value (the display value that shows when the input is at 5V). This can also be changed using the Up and Down switches.

Finally, pressing switch S2 again shows the display dimming value. This sets the minimum display brightness that occurs in darkness. The value can be reduced or increased using the Up and Down switches to adjust the minimum brightness, as required.

Display Unit Parts List

1 double-sided PCB, code 05106122, 80 x 50mm
1 plastic utility case, 83 x 54 x 31mm.
1 piece of red transparent Perspex or Acrylic sheet, 82 x 54 x 3mm
4 SPDT micro tactile switches with a 6mm actuator (S1-S4)
1 3.5mm stereo jack plug
1 LDR with 48kΩ light resistance
1 DIL40 IC socket, 0.3-inch width (cut to DIL30)
1 DIL18 IC socket
1 3-6.5mm IP65 cable gland
1 M3 x 10mm screw
1 M3 nut
4 PC stakes
1 2m length of twin shielded cable
1 500Ω multi-turn trimpot (3296W type) (Code 501) (VR1)

Semiconductors

1 PIC16F88-I/P microcontroller programmed with 0510612B.hex (IC1)
3 13mm common anode red LED displays (DISP1-DISP3)
3 BC327 transistors (Q1-Q3)
1 LM317T adjustable regulator (REG1)
1 1N4004 1A diode (D1)

Capacitors

2 100µF 16V electrolytic
1 10µF 16V electrolytic
1 100nF MKT polyester
1 10nF MKT polyester

Resistors (0.25W, 1%)

1 22kΩ
6 2.2kΩ
1 10kΩ
1 120Ω

Resistor arrays

1 100Ω x 5-resistor isolated 10-pin SIL array (eg, Bournes 4610X-102 100R)
1 100Ω x 3-resistor isolated 6-pin SIL array (eg, Bournes 4606X-102 100R)

Note: 8 x 100Ω resistors can be used instead of the resistor arrays

That's all we have space for this month. The final article next month details the oxygen sensor installation and describes how the Wideband Controller is used. SC

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SERVICEMAN'S LOG

The solar panel system that almost caught fire

Dave Thompson*

Many homes have had solar panels installed over the last few years, usually ranging from about 1.5kW up to 4kW. But how safe are they, especially if they have been installed in a rush to meet subsidy deadlines?

This month, I'm kicking off with an interesting story from P. W. of Hope Valley, SA. He recently had a rather worrying encounter with a solar panel installation that nearly caused a fire. Here's how he tells it . . .

We recently had a 1.5kW solar system installed on our home and shortly after, our neighbour installed a 3kW system. In each case, the inverter was installed adjacent to the external meter box at the front corner of the house. In fact, both inverters and their associated LCD readouts were visible when standing alongside my meter box.

Being interested in the system's performance, I soon got into the habit of reading and recording the solar energy meter and the network import/export meter for my installation at about the same time each day. And because it was adjacent, I also occasionally compared the daily output of my system with that of my neighbour's.

One day, however, I noticed that his system had shut down. I duly knocked on his door to let him know this and together we attempted to restart the system. We opened the AC solar system circuit breaker and then the adjacent DC isolator and then attempted to restore them in reverse order. The only obvious problem was that the DC isolator would not remain in the open position and would immediately spring back to closed when released. The inverter also seemed to attempt to start up, with indications from the LCD panel, but would shut down after a few seconds.

In the end, it looked like there was some sort of fault with the inverter's DC isolator, so I left my neighbour who was now intending to phone the installer for a warranty call-out. About 30 minutes later, however, he came in and said that he had climbed onto his roof to inspect the panels and had detected a strong odour that smelt like burnt electrical equipment. And he asked whether I could help him out as he knew that I had skills in this area.

I climbed onto the roof with him and confirmed that the smell came from the vicinity of the roof-top solar panel DC isolator. The plastic box was quite hot to the touch and as we were inspecting it, the sun came out from behind a cloud, providing full solar energy. That gave us our first real clue because we now observed wisps of smoke coming from around the gland where the cables from the panels entered the box.

We immediately opened the isolator but the switch mechanism felt rather vague, rather than giving a positive clunk. By this stage, I was quite concerned about the smoke and suggested that my neighbour bring his portable fire extinguisher up immediately. This was done and we then contemplated what to do next. Clearly, the panels were not yet isolated and I thought it unwise to open the inter-panel socket connectors under load.

This was further complicated by the fact that the solar array was connected in two strings and the lower string connectors were somewhere under the panels and could not be reached from any side.

In the end, I suggested that we cover the panels with drop sheets to remove the solar energy source before opening the plugs. This was quickly achieved and the accessible top section was easily unplugged.

The lower section needed one panel to be slid down to access the plugs. As a result, a hex key was used to loosen the mounting screws, after which the panel was slid down and the lower section of the array unplugged

Now that the panels were electrically isolated and fire-safe, we removed the lid from the DC isolator box to be greeted with a blackened, melted, stinking mess. The isolator switch itself was a 4-pole unit, with the two pairs of DC solar panel cables paralleled into two of the poles at one end and the positive and negative cables to the inverter exiting the other two poles from this same end.

At the other end of the isolator there were two single-cored (stranded conductors) jumper cables joining the positive and negative incoming and outgoing poles. The fault was clearly at this end of the assembly. The insulation on these two wires had melted and the copper cables were blackened. The resultant carbon around the cables was now providing an effective positive-to-negative electrical short on the DC supply from the panels, thereby preventing the inverter from functioning.

There were several possible causes for this fault: (1) the current-carrying capacity of the single-core jumper cable was inadequate to cope with the output from two solar panel strings (unlikely) or (2) the terminals were not sufficiently tight (possible) or (3) the fine stranded cable used was unsuit-

Items Covered This Month

- The solar panel system that almost caught fire
- White goods jinx
- NEC PXT42XD2 106cm plasma TV
- Lafayette HE-30 communications receiver
- Intermittent ECU in Rover 3500SE

**Dave Thompson, runs PC Anytime in Christchurch, NZ.*

able for the isolator connector type, thereby producing a high-resistance joint (also possible).

As we stood there on the roof, we contemplated the possibility that the box could have caught fire and set fire to the house, perhaps even spreading to my adjacent property as the gap between the houses is only about 2.5 metres. And because it was late December, we both could also have been away from our homes on holiday and possibly been recalled to a disaster.

What was interesting was that both my neighbour and my wife had also detected the occasional smell of something burning over the previous few days, so the problem could have been evolving for some time.

In my opinion, this is an example of either incorrect material selection or poor workmanship and is completely unacceptable for an installation that has been in service for just four months. One wonders how many other installations have been made using this exact same configuration and whether it is just a matter of time before they also fail.

It's also possibly another case where knee-jerk government subsidy programs and deregulation (no independent inspections of electrical installations) have created a climate where substandard installation practices can easily exist. The resulting installation stampedes to meet subsidy cut-off deadlines certainly don't help either.

I was initially surprised that the box had not already caught fire, given that potentially there is 3kW of energy available from the solar panels. However, solar panels have a relatively high internal resistance so that they only deliver a short circuit current of just above full load current. This characteristic ensures that the current and hence the energy into a short circuit is limited and could explain why a fire had not started.

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column in Silicon Chip? If so, why not send those stories in to us? In doesn't matter what the story is about as long as it's in some way related to the electronics or electrical industries, to computers or even to car electronics.

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

Whitegoods jinx

Now for a couple of my own stories, although I have to admit they are not exactly about electronic servicing.

Just lately, it seems that I have been jinxed when it comes to my home appliances, with both my fridge and washing machine failing in rapid succession. And in both cases, I had to call in an expert to fix the problem, despite having a fair idea what the fault might be.

In my opinion, the inconvenience caused when an appliance goes wrong is usually directly proportional to the convenience it provides when it works. Fridges and washing machines certainly fall into that category.

Recently, I noticed that the milk felt a little warmer than usual but since the temperature in our Westinghouse fridge/freezer does seem to wander a little, I wasn't initially overly concerned. However, when I opened the fridge door the next morning, I was greeted by a warm breeze instead of the frigid draft I usually get and while I'm no refrigeration engineer, warm air from a fridge can't be good (to state the obvious).

The freezer section, which is underneath the fridge compartment (right where it should be in my opinion), appeared to be running normally, however. It was still as cold as it should be so it seemed that the fault was confined to the top compartment only.

Unfortunately, what I know about fridges could be written in block capitals on a postage stamp, so I did what any red-blooded male would do – I hit Google to see if I could find any information on the problem. After all, with any luck, it might be something I could fix myself and save a service fee.

Unfortunately, I could find next to no information about it online which was rather disappointing. After all,

~ IT'S BETTER TO LET THE PROFESSIONALS HANDLE IT & NOT GO OFF ON A WILD GOOSE CHASE

this unit is from a reasonably big-name manufacturer and while their fridges may not be available in all world markets, I would have thought enough had been sold in our part of the world to generate at least some Internet buzz.

I even tried looking at Google's image results of the fridge name and model number. There were many similar looking units (white with two doors!) but none jumped out as being identical other than those on a few online stores selling the same model fridge.

Aside from those results, there were also countless references to user manuals but nothing for my particular model. However, there were lots of manuals for similar models so I downloaded them, hoping that their troubleshooting sections would shed some light on the reason for the warm fridge compartment.

As it turned out, these manuals were helpful. First, I learned that in this type of fridge, all the cooling is done in the freezer compartment and a fan blows cold air upwards through a series of ducts into the space between the inner and outer "shell" of the fridge compartment. If the freezer was still working, then the issue was as simple as something preventing cold air getting to the top half of the unit.

There were several possibilities. First, the ducting could be iced up, physically blocking the airflow. Because of ice build-up in these ducts, fridges use de-icing heaters, typically controlled by a thermostat, to clear them. If the thermostat fails, ice eventually blocks the ducts and the cold air cannot circulate, resulting in a warm fridge compartment.

The de-icing system explains the odd noises our fridge sometimes makes; we often hear "cracking" noises and other weird sounds, which is probably the ice thawing.

Another cause of a warm-fridge symptom is the fan not running. When I read that in the manual, I realised that I hadn't heard the fan lately. The manual suggested holding the door open and listening for the fan, which apparently should start up when the door is opened.

Well, I did what they suggested but couldn't hear anything. However, given that the fridge compartment was warm, you'd imagine that the cooling system – which is also thermostatically controlled – should have had the fan going nuts, trying to bring the compartment temperature down. Since that wasn't happening, I could only guess that either the thermostat and/or the fan was kaput.

Unfortunately, even though I'd determined what the problem could be, I couldn't do much about it. I didn't know where to source spare parts or even who possible local suppliers were. And as disappointing as that was, I've learnt over the years that sometimes it's better to let the professionals handle it and not go off on a wild goose chase.

Now I used to drive past a few likely repair businesses on the way to and from work but they've now all gone because of the quakes. It was then I remembered that a whitegoods repair company had recently moved into a shop literally just around the corner from my workshop; I just hadn't got used to them being there yet.

Anyway, I called them and they said they'd send a guy out. The serviceman was excellent; he was fast and friendly and the company turned out to be a small, father-and-son business which had migrated to the suburbs after their Christchurch city base was destroyed.

I purposely didn't tell them what I thought the problem was, other than describe the symptoms (ie, freezer OK but fridge warm). My reason for this was simple: I don't particularly like it when I walk into a job and the customer immediately launches into the "I reckon this is the problem and all you need to do is . . ." speech. This pre-emptive strike drips with all sorts of implications and depending on the circumstances, can make things uncomfortable.

First, it implies that the client thinks he knows it all and will likely be scrutinising (and perhaps even questioning) every move the repair guy makes. It also implies that the problem is so simple that the client could fix it if they could be bothered and the serviceman really should charge less for the job because the client has already done all the troubleshooting work.

In this case, it was gratifying to observe that the repair guy followed much the same initial troubleshooting path I'd taken before using a multimeter to confirm that the fan motor was the problem rather than any of the thermostats or blocked ducts. He also had a spare motor in his van and it took him no more than 15 minutes to swap it out by simply pulling the fan assembly from the old motor's armature and pushing it onto the new one. The total cost was $120, including the motor.

I seriously doubt whether I could have done the job for any less than that, even if I'd known exactly what was wrong and could source the part. And for $120, it simply wasn't worth the time I would have wasted.

Ditto for the washing machine

I'd no sooner got the fridge fixed than my washing machine decided to also chuck a wobbly. And as with the fridge, I hit the web for answers and came up with some possible answers but was again unable to act on them other than call an expert.

The machine is question is a Samsung front-loader which we bought some 10 years ago when our old machine failed. It turned out to be a very good machine and has always performed flawlessly – until, that is,

the day we arrived home to the proverbial flooded laundry.

After unplugging the machine and mopping up the mess, I got down to finding the source of the leak. I assumed that the seal on the front of the machine – the large circular rubber one the glass door shuts onto – would be the likely culprit, so that's the first thing I checked. It actually looked pretty good to me and from what I could gather from the information online, when they do fail they usually start leaking slowly and then gradually get worse rather than just suddenly letting go.

So it was back to the drawing board as they say. Closer examination revealed a large amount of slimy brown "goo" covering a lot of the bits I could see inside the machine, especially around the powder drawers at the top. This didn't look right at all. I searched for information on the web but found nothing useful from a repair point of view other than people saying it was sometimes normal to have some build-up on various parts and to clean it where possible.

Some users also suggested looking at the filters to make sure they were clear. They were and I now realised it was time to call in an expert. The problem was that nobody we called had any experience with Samsung machines and when we mentioned that it was a front-loader, most of them could only guffaw "good luck with that!" over the phone.

I kept calling and eventually my persistence paid off when I found a company claiming lots of experience with front-loaders, including Samsung machines. However, when it came to booking a time, the nearest he could give me was "morning or afternoon". I was somewhat miffed that they couldn't offer me a more precise time but lacking any other options, went ahead with the booking anyway.

In the event, the serviceman arrived on-site sooner rather than later and nailed the problem quickly. He immediately asked if we used a certain brand of powder, which we did, and then told us not to because it clogs up these machines. He then spent 20 minutes cleaning and flushing the machine out.

It turned out that the flood had come from the powder drawer. When it's all working normally, water pours into this drawer and drains from holes in the bottom into the machine. In our case, the holes in the drawer were completely clogged, so the water just poured onto the floor. Lesson learned!

NEC 106cm plasma TV

Flat-panel TVs are often too expensive to repair, especially when labour costs are factored in. And even if it is an economic proposition, it doesn't take much for an owner to decide to scrap a faulty set and buy a new one.

Part of the problem is the cost of replacement modules. But if a faulty module can be repaired at component level, then that can make for a whole new ballgame. K. G. of One Tree Hill, SA, recently had a win with an NEC plasma. Here's how he tells it . . .

This repair story concerns an NEC plasma 106cm TV, model PXT42XD2, which has an LG PDP42X chassis. The owners are acquaintances of mine and I saw the TV at their place lying face down on the sofa. When I asked them about it they said they had wanted to play DVDs though it but there wasn't any sound and then they couldn't operate it properly as the remote control didn't seem to function.

They had then bought a new universal remote but couldn't make that work either, despite trying all the programming codes for NEC TVs. They had subsequently been quoted $500 for a replacement sound module but decided it wasn't worth fixing.

Momentarily lacking better judgement, I volunteered to have a look at it for them to see if I could fix it more cheaply. So my very patient wife and I loaded it into the back of the car and took it home.

When I set it up on the workbench and turned it on, I was greeted with the NEC logo and then, a few seconds later, a "No Signal" message which moved around the screen. It was difficult to do other checks with the remote control not working so I decided to look into that first.

The new universal remote didn't respond to programming using the instruction sheet so I took the original one apart and had a good look around. Connecting its PCB to a bench power supply enabled me to test the unit as a

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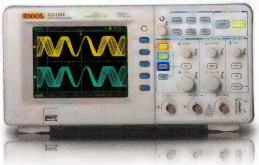

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I TOOK THE ORIGINAL ONE APART AND HAD A GOOD LOOK AROUND...

bare board without the complications of batteries etc. I used a recycled IR detector device and a CRO to monitor the output of the IR LED in the remote.

Sure enough, there was a healthy-looking stream of pulses from the detector when any of the buttons was pressed. I then reinstalled the PCB in its case, replaced the batteries and repeated the test. This time, there was no output, so it had to be something to do with the battery.

A close inspection of the battery holder and its contacts revealed that the positive contact had been pushed back into the housing, so that it no longer made contact with the battery's positive end. Simply bending the contact back out and cleaning it with fine emery paper fixed the problem and I was then able to operate the TV with the remote control.

Now for the TV itself. I laid it face down on a pair of padded saw horses and removed the 20 or so screws holding the rear cover in place. However, it wasn't immediately obvious where the audio section was because I couldn't see any ICs that looked like conventional audio power amplifier chips. As a result, I removed the 10 screws which secured the cover over the speakers and then traced the speaker wires back to the board containing the audio amplifiers (this board also accommodates the RF tuner).

I duly noted the type number of the board (569HB0353B) and checked to see if a new one was available. It was but the cost including delivery was $234. This was better than $500 but it didn't include my labour and, in any case, I didn't think the owners would agree to it.

It was time to see if I could actually track the fault down and fix it. The nearest IC to the speaker connector was a 20-pin TSSOP surface-mount package with a 0.65mm pin spacing. It's quite a small package for an audio power amplifier and by using a torch and magnifying glass and I was able to read the type number as MP7722DF.

The internet really is a wonderful resource for information, particularly data sheets. The one for this device indicated that this tiny package was able to produce 20W from each of its two channels. The data sheet also indicated that it used switchmode (Class D) operation to achieve the necessary high efficiency.

I guessed the chip itself was probably OK when I tapped one leg of an electrolytic capacitor adjacent to the IC with a multimeter probe and faint clicks could be heard from the speakers with power applied.

One IC I did recognise on the board was a CMOS 4052 2-channel 4-position analog switch IC. This looked as though it selected between the various AV inputs but there were no clicks when I touched the pins of this device.

Next, I turned my attention to a large SMD IC nearby with 25 closely-spaced pins on each of its four sides. The type number didn't turn anything up on the net but I guessed it was a type of audio digital decoder. There was a small 24.576MHz quartz crystal next to the package and it crossed my mind that maybe, just maybe, the crystal was shot. These mass-produced crystals can certainly give trouble at times.

I propped the board up vertically and saw that the crystal pins extended some way below the board. This allowed me to get a CRO probe clipped on securely enough to measure the waveform on each pin of the rock. The scope showed only noise on both pins – not the 24.576MHz sinewave of a few hundred millivolts that would be expected.

My stock of crystals is separated into various drawers, each covering a frequency range of a few MHz. The 24-30MHz drawer contained an assortment of old 27MHz CB crystals plus a couple on 24MHz exactly. And then, lo-and-behold, there was one right on 24.576MHz. How lucky can you get?

This crystal was taller than the original one in the TV but the pin spacing was the same. I lost no time replacing it and this time when I checked it with the scope, up came the expected 24.576MHz signal with good amplitude.

I have a 146MHz ham radio antenna on a pole next to my workshop and I connected this to the RF input of the TV. And that was it – as soon as I selected a station, sound burst forth from the speakers.

So the crystal was the problem and its frequency must be common to other applications for me to have one in the junkbox. I put the covers back on and took the unit inside the house for a more thorough checkout. This showed that the TV was working normally and so it was returned to its owners.

Communications receiver

My next story is from J. A. of Narangba, Qld who recently repaired a communications receiver. It had an unusual manufacturing fault . . .

A few weeks ago, I was given a pristine Lafayette HE-30 communications receiver with the comment "Dad had it from new but it was never any good. It has a very loud hum but it might be useful for parts".

Knowing the reputation Lafayette had for producing excellent radios, I felt that there must have been something seriously wrong for this to occur. Sure enough, when I tried it out, there was a lot of 50Hz hum overriding the signals so I decided to see if I could track down the cause.

My first step was the check the internet, to see what information was available for this receiver. The first item I found told me that the radio came in two versions: (1) the HE-30 which was supplied as a fully functional radio and (2) a KT-320 which was a kit that you had to put together. It looked like the unit I had fell into the latter category.

After downloading the circuit diagram, I removed the bottom cover from the receiver and was surprised to see several electrolytic capacitors hanging

Intermittent engine control module in a Rover 3500SE

Intermittent electrical faults in cars can certainly take some tracking down, especially when they occur only briefly at widely-spaced intervals. R. L. of Oatley, NSW had one such experience with a Rover 3500SE V8 . . .

In the late 80s, I bought a 1983 Rover 3500SE V8 which was a really nice car. It was fitted with a then state-of-the-art Lucas/Bosch electronic fuel-injection and electronic ignition system and it performed very well indeed.

Some years later, the car began having an intermittent problem, the symptoms being rough idling and lack of power. These symptoms would normally last no more than about 5-10 seconds and then not reoccur for months.

The intermittent nature of the fault, coupled with the long time periods between occurrences, made it pointless taking the car to a dealer or a mechanic. So there was nothing for it but to tackle the job myself.

After obtaining a service manual and studying the electrical diagrams, my initial thoughts were that the problem was probably in the ignition system. As a result, I meticulously checked the connections on the ignition module and the distributor sensor for any loose wires or contamination but found nothing.

I had no sooner finished doing this when the car played up again for the usual short period. By now, I suspected that the fault may be in the ignition module itself so I replaced both it and the Hall Effect sensor for the distributor ($300). It played up again a few months later but at least I now knew that the ignition module and Hall Effect sensor were OK.

Further reading of the manual now led me to the fuel injection system. I checked all the injectors and their connections and the signals coming from the engine control unit (ECU) but everything appeared normal. The car then played up yet again for about 15 seconds a short time later.

In desperation, I made an inquiry at a Rover Service Centre and they suggested a new ECU. This was priced at $600, a lot of money in 1993. Even so, I was tempted until I found out that by then the ECU modules were no longer in production and all I would get was a reconditioned exchange unit.

Not wanting to go down that route, I decided to remove the ECU and check it thoroughly for dry joints, leaky capacitors and signs of contamination, etc. Unfortunately, Rover had decided to mount the ECU in a very safe environment, under the passenger floor. This meant that I had to remove the carpet and the false floor to access it.

Anyway, I did this and took the ECU to work where I had access to a powerful microscope. After carefully disassembling the unit, I examined all the solder joints on the main board and when I got to the output power transistors I saw that the emitter connections looked like dry joints.

This fuel-injection control unit only pulses the injectors on the two banks of the engine alternately, so there are only two output transistors. And if one of these briefly ceased operation due to bad solder joints, the corresponding engine bank would be starved of fuel and the engine would run rough and lack power.

As a result, I removed all the solder from the output transistors connections and resoldered them. I then double-checked the rest of the board for similar problems before reassembling and reinstalling the ECU.

And that was it – the car never missed a beat again. Obviously, one or more dry joints on the output transistors would go open circuit occasionally and although it only caused minor inconvenience, it almost certainly would have become worse over time.

Finally, just a short comment on the electrical reliability of English cars. I owned this one for quite some time and this was the only electrical fault I ever had!

off the main DC supply line by their pigtails. Suspecting that these were not part of the original design, I checked the circuit diagram and sure enough, my suspicions were confirmed.

Initially, I decided to take everything back to square one and rebuild the power supply as per the circuit. Having removed the excess electros, I then found that a choke had also been added. This choke was actually an old speaker output transformer, which is fine as some old equipment used electromagnetic speakers and the transformers also served as chokes. The only problem was that, in this case, the secondary output leads had been cut off and were shorted to the transformer frame.

As a result, this choke was also removed and I then set about tracing out the power circuit. This quickly paid dividends because I immediately found two basic faults with the power supply. First, instead of the HT output coming from the cathode of the rectifier valve (5CG4), someone had made the connection to plate 2 which meant there was very little HT applied to the radio, hence the 50Hz hum. Second, a 47μF electrolytic capacitor had been connected between the two main electros, with the negative side to the main output.

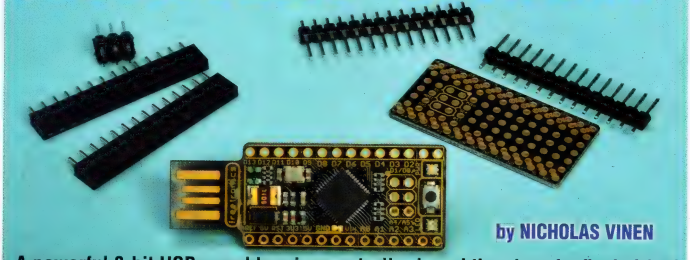
Restoring the power components as per the circuit diagram immediately removed the hum but the overall performance was down on what I would have expected. What's more, the IF gain control caused a real "feedback" howl as it was advanced.

Tracing the circuit through, I found that the wiper of the IF gain control had been connected to the primary of intermediate-frequency transformer IF4 instead of to its secondary. The reason was simple – the IF transformer had been installed with the incorrect orientation.

Positioning it correctly solved all the feedback problems and the radio was now working quite well. I then realigned the four IF transformers and replaced two 6BA6 valves and this really brought the radio brought the old radio to life.

For its age, it's a nice piece of equipment, although it's not up to the standard of modern solid-state receivers. Basically, it had sat unused for over 35 years because of some simple wiring errors when it was originally assembled! SC

Freetronics "LeoStick"



by NICHOLAS VINEN

A powerful 8-bit USB-capable microcontroller board the size of a flash drive! And our publisher was so chuffed that they'd name a board after him . . .

The "LeoStick" has to win the prize for the cutest microcontroller development platform.

It's (mostly) compatible with the Arduino system and plugs straight into a USB port – no cable or connector required. Normally it's powered from the USB but a separate power supply can be used if desired.

It's slightly thicker than a typical PCB and has gold-coated pads on a small projection, arranged in the right layout to make contact with the four USB pins.

Like other Arduinos, this one features an 8-bit Atmel AVR microcontroller. In this case it's an ATmega32U4 which has built-in USB support. That makes this a much neater (and smaller!) solution than the majority of Arduino boards which tend to use separate USB-to-serial chips.

On board are two RGB LEDs, one for power/USB activity and the other for the user software to control. There's also a tiny reset button, a piezo buzzer and a row of pads on either side to accept socket strips, pin headers or wires. The pads include 14 digital I/Os (seven of which can be PWM outputs) and six analog inputs which can also be used as digital I/Os.

There are also pads to access the power supply and other pins, including the ADC reference voltage. Note that four of the digital I/Os are shared with the user LED and piezo buzzer.

One option for adding circuitry to the LeoStick is to purchase a Freetronics ProtoStick pack which gives you a PCB with 14 x 4 holes of prototyping area and a couple of pin headers. This plugs right into the LeoStick once you've fitted the provided socket strips to it.

That isn't a great deal of prototyping area but it's big enough to get a small DIP IC and some passive components on, or just break the signals you need out to a connector (eg, IDC to connect a ribbon cable).

The LeoStick also has six pads arranged in a 3x2 matrix which allows you to install a standard Atmel in-circuit serial programming header. That means the LeoStick can be used as a general purpose ATmega32U4 breakout board, which allows you to use all 32KB of on-board flash memory. If you program it over USB, you typically lose 4KB to the bootloader code.

One of the best new features of the LeoStick, compared to earlier Arduino boards, is its ability to appear as a variety of USB devices. Arduinos with USB typically appear as a serial port which allows you to upload code to the chip and also send data back and forth between the host PC and your application.

The LeoStick is not different but it also appears as a keyboard and mouse (human input device or HID) and can therefore send key press or cursor move events to the host computer.

In theory, it can appear as any type of USB device, including "mass storage" (ie, a hard disk) but that would require custom USB code. As mentioned earlier, USB communications is handled by the micro itself and this gives more flexibility than boards which use an intermediate chip.

We spent a little time programming the LeoStick. While installing the required software requires a few additional steps, the instructions that come with the LeoStick are easy to follow and we had no problems getting it up and running.

The LeoStick is based on the Arduino Leonardo; it's essentially a shrunken version of that design. While the Leonardo is an official Arduino board, it's a relatively new one and so you need to install extra files to make the Arduino development software support the LeoStick properly.

This support is "not yet perfect" although it generally works well. For example, at the time of writing, you can't use PWM to drive the on-board piezo buzzer. This is planned to be fixed soon and may already have been sorted out by the time this goes to press.

It took us less than ten minutes to set up the software and get a program working on the LeoStick. With 28KB of flash program memory available, 1KB of EEPROM, 2.5KB of RAM and an operating speed of 16MHz, this unit is quite capable and can be programmed for a variety of tasks.

As well as its tiny size and portability, the other nice thing about the LeoStick is the price. It retails for under $30 and is available from Jaycar Electronics (www.jaycar.com.au) in Australia and New Zealand (Cat No XC4266). The ProtoStick "shield" board is $7.95 (XC4268). SC

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More Arduino Kit Projects on page 2 & 3

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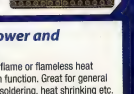

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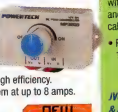
Crazy Cricket & Freaky Frog Kit

Refer: Silicon Chip Magazine June 2012

A fun first project for a budding electronics enthusiast. Designed to imitate the chirping noise of a cricket or gentle croaking of a frog (alternates at power up), while keeping its location secret to annoy other family members. it activates in darkness and stops when disturbed by light. Kit supplied with PCB, pre-programmed IC, battery and electronic components.



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- Current: Up to 20A

RR-3420

NEW $1.90

80 Channel UHF Transceivers

Complete with rechargeable batteries, dual charger cradle and a range of accessories. They have 0.5 watt output for up to 5km transmission range and CTCSS function.

- Sold as a pair
- No licence required
- 80 channels and 38 sub-channels
- Spare battery to suit DC-1029 $14.95

DC-1027

NEW $114.00

8Bit 257 Step Digital Pot

More Electronic Components on page 7

MCP415-103E/P 10k0hm

Useful in circuits that require precision control. They can be used for example in the feedback network of an op amp to provide precise variable gain control, or filters to allow accurate adjustment of the filter properties.

ZX-8879

NEW $2.15

Arduino Compatible Boards

100% Arduino compatible, designed in Australia and supported with tutorials, guides, forum and more at www.freetronics.com.

- ATmega328P MCU running at 16MHz
- 14 digital I/O lines (except EtherMega with 54 lines)

"Eleven" Arduino-compatible development board

An incredibly versatile programmable board for creating projects. Easily programmed using the free Arduino IDE development environment, and can be connected into your project using a variety of analog and digital inputs and outputs. Accepts expansion shields and can be interfaced with our wide range of sensor, actuator, light, and sound modules.

- 8 analog inputs

XC-4210 **$39.95**

EtherTen, Arduino-compatible with Ethernet

Includes onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, and even Power-over-Ethernet support.

- 10/100base-T Ethernet built in
- Used as a web server, remote monitoring and control, home automation projects
- 8 analog inputs

XC-4216 **$69.95**

USBDroid, Arduino-compatible with USB-host support

This special Arduino-compatible board supports the Android Open Accessory Development Kit, which is Google's official platform for designing Android accessories. Plugs straight into your Android device and communicates with it via USB. Includes a built-in phone charger.

- USB host controller chip
- Phone charging circuit built in
- 8 analog inputs
- MicroSD memory card slot

XC-4222 **$69.95**

EtherMega, Mega sized Arduino 2560 compatible with Ethernet

The ultimate network-connected Arduino-compatible board: combining an ATmega2560 MCU, onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, Power-over-Ethernet support, and even an onboard switchmode voltage regulator so it can run on up to 28VDC without overheating.

- 10/100base-T Ethernet built in
- 54 digital I/O lines
- 16 analog inputs
- MicroSD memory card slot
- Prototyping area
- Switchmode power supply

XC-4256 **$119.00**

Breadboard Jumper Kit

This kit consists of 70 pieces of single core sturdy wire which has been stripped on each end and bent at right angles.

- Specifically made for breadboards
- 5 packs each of 14 different length

PB-8850 **$11.95**

Spend over $50 on Arduino Boards and get $10 OFF on Active & Passive Components

Offer applies to XC-4266, XC-4216, XC-4210, XC-4256 & XC-4222

ProtoShield Basic

A prototyping shield for the Eleven (XC-4210) and USBDroid (XC-4222). Provides plenty of space to add parts to suit any project, keeping everything neat and self-contained. includes dedicated space to fit a power LED and supply decoupling capacitor.

- Gold-plated surface

XC-4214 **$4.45**

ProtoShield Short

A dedicated short version prototyping shield for EtherTen (XC-4216) and EtherMega (XC-4256). This special prototyping shield is designed to fit neatly behind the RJ45 Ethernet jack, allowing you to stack your Ethernet-based projects right on top with standard headers.

- Pads available to fit a reset button
- Gold-plated surface

XC-4248 **$4.95**

433MHz Receiver Shield

This receiver shield lets you intercept 433MHz OOK/ASK signals, decoding them in software on your Arduino. All the Arduino headers are broken out to solder pads, and GND and 5V rails are provided for convenience.

- Reset button
- Blue "power" LED
- Red and green user-defined LEDs
- Gold-plated surface
- 433.92MHz tuned frequency

XC-4220 **$29.95**

Mega Prototyping Shield

Fits the EtherMega (XC-4256) and Arduino compatible "Mega" size boards so you can fit your own parts for projects. Includes header pin sets.

- Over 300 general-purpose plated holes for your parts
- Handy 5V and GND rails
- All Arduino I/O header pins branched out for your use
- Gold-plated surface
- Reset button

XC-4257 **$17.95**

Terminal Shield

A special prototyping shield for the Eleven (XC-4210) and USBDroid (XC-4222) that provides handy screw terminals on both edges for easy and secure connection.

- Power LED
- 3 user-definable LEDs: red, green, and blue
- Stackable headers
- Gold-plated surface

XC-4224 **$16.95**

N-MOSFET Driver & Output Module

This high-power N-MOSFET module lets you switch high-current loads using a tiny microcontroller. Works brilliantly for automotive projects such as switching high-power 12V lights and high wattage LEDs.

- Maximum 60V / 20A switched load
- Multiple connection headers for high-current wiring
- Built-in pulldown resistor to ensure output is off by default
- Drive directly from an Arduino digital output

XC-4244 **$6.95**

Microphone Sound Input Module

Give your project ears with this sound response and sound pressure level sensing module. An integrated dual signal amplifier converts the sound to separate channels for pulse and frequency measurement, and sound volume level. Designed to connect straight to an Arduino compatible, microcontroller Analog to Digital converter or many other circuits.

- Omnidirectional microphone
- Frequency response 60Hz to 15KHz
- Sensitivity -40dB typical

XC-4236 **$9.95**

Humidity & Temperature Sensor Module

Measure temperature and relative humidity using a simple interface that requires just three wires to the sensor: GND, power, and data. Supported by an Arduino library that makes it very easy to read values into your project, so with a single I/O line from your microcontroller you can read both temperature and humidity.

- -4°C to +125°C temperature range with +/-0.5°C accuracy
- 0-100% relative humidity with 2-5% accuracy
- 3 to 5V operation
- Blue power LED

XC-4246 **$19.95**

Stackable Header Set

The perfect accessory to the Eleven, Etherten, USBDroid, Protoshields and vero type boards when connecting to your Arduino compatible project. Stackable headers have female sockets on the top side and male pins underneath.

- 0.1" pitch
- 2 x 8 pin and 2 x 6 pin

HM-3207 **$2.95**

To order call 1800 022 888

All savings based on Original RRP. Limited stock on sale items. Prices valid until 23/07/2012.

ARDUINO PROJECT KITS

Arduino Displays

LCD & Keypad Shield

Handy 16-character by 2-line display ready to plug straight in to your Arduino, with a software-controllable backlight and 5 buttons for user input. The display is set behind the shield for a low profile appearance and it includes panel mounting screw holes in the corners.

- 2 rows of 16 characters
- Supported by a driver library
- Software-controlled backlight
- Reset button

XC-4218 **$29.95**

Large Dot Matrix Display Panel

A huge dot matrix LED panel to connect to Eleven (XC-4210), EtherTen (XC-4216) and more! This large, bright 512 LED matrix panel has on-board controller circuitry designed to make it easy to use straight from your board. Clocks, status displays, graphics readouts and all kinds of impressive display projects are ready to create with this display's features.

- 32 x 16 high brightness Red LEDs
- 5V operation
- Viewable over 12 metres away
- Tough plastic frame
- Controller IC's on board, simple clocked data interface

XC-4250 **$39.95** NOTE: Can for comparison only.

Real-Time Clock Module

Perfect for clock projects, dataloggers or anything that needs to know the date and time. Keeps accurate time for years using a tiny coin-cell, and is very simple to connect to your Arduino project. A driver library allows your program to easily set or read the time and date.

- Battery included

XC-4272 **$29.95**

Power-over-Ethernet Regulator

This regulator module fits onto the EtherTen (XC-4216) or EtherMega (XC-4256) to make them compatible with commercial 48V Power-over-Ethernet switches. It includes built-in smarts to communicate with the switch and negotiate a power rating for the device, then uses a switch-mode regulator to efficiently drop the 48V supplied via the LAN cable down to 7.5V for use by the Arduino compatible board.

- Implements the official 802.3af Power-over-Ethernet standard
- 48VDC in, 7.5VDC out
- 12.5W maximum power rating

XC-4252 **$29.95**

Sound & Buzzer Module

This versatile piezo-element module can be used for both input or output! Also used as a noise-maker driven by your microcontroller for audible feedback of events, and as a knock-detector input to sense events and react to them. Includes a built-in 1M resistor to allow the piezo element to detect shocks.

- Frequency response 0-20KHz, peak resonant frequency: 4KHz +/-500Hz
- Sound pressure level at 10cm: 75dB (min)
- 1 to 25V rated voltage (3 to 5V typical)

XC-4232 **$9.95**

Logic Level Converter Module

This module easily connects different logic voltage levels together for bi-directional communication on up to 4 channels, allowing you to use low-voltage sensors with a 5V microcontroller.

- 4 bi-directional channels
- Easily connect 3.3V sensors and devices to 5V microcontrollers
- Pass-through GND connection

XC-4238 **$6.95**

Full Colour RGB LED Module

Includes a bright RGB LED on the top of the board and a WS2801 constant-current, addressable, multi-channel LED driver on the back. This smart module can be daisy-chained, so you can connect a number of these together in a string and drive each of the module colours individually from your microcontroller. The WS2801 includes its own built-in PWM outputs.

- 3.3 to 5V operation
- Constant current controller

XC-4234 **$9.95**

3-Axis Accelerometer Module

Easy to use 3-axis accelerometer that provides separate outputs for X, Y, and Z. Very simple to connect to an Arduino or other microcontroller using analog inputs, and easy to read the values into your program or circuit directly.

- Selectable +/-1.5g and +/-6g ranges
- Freefall-detection (0g) output
- Built-in 3.3V regulator with 5V-safe I/O lines

XC-4226 **$19.95**

Temperature Sensor Module

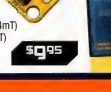
Sprinkle these around your house to collect temperature data using your Arduino. This 1-wire bus temperature sensor module is easy to connect and use. You can even daisy-chain several together on the same wire. 0.5°C accuracy and fast response.

- -55 to +125°C temperature range
- Selectable 9 or 12 bit precision
- Arduino compatible library and examples support
- Unique device ID coded into every sensor
- Two sets of header connections to allow easy daisy-chaining

XC-4230 **$16.95**

Hall Effect Magnetic & Proximity Sensor Module

Sense magnetic presence, rotating wheels and magnets, door and arm sensors, and anything else magnetic nearby this sensor.



- Green "triggered" LED for easy setup and use
- Output turns on at 40 Gauss (4mT) and turns off at 30 Gauss (3mT)
- 2.5 to 5.5V operation

XC-4242 **$9.95**

For Arduino Video & Projects Visit

www.jaycar.com.au/arduino

Follow Us on Twitter

Twitter.com/JaycarAU

4 Channel PoE Midspan Injector

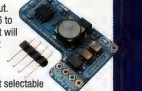
Power up to 4 EtherTen's or EtherMega's with DC from a low cost plugpack across your home or office network cables. This takes all the hard work out of cutting and hacking ethernet cables to power remote boards, it isolates and powers the correct wires automatically.

- 4 channels of input/output jacks
- Can be connected directly and powered by standard network cables on the output side Commercial
- Power-over-Ethernet sources are not required
- Blue power LED
- Mounting holes

XC-4254 **$26.95**

Power Regulator 28V (Switchmode)

This regulator is a high tech switchmode supply with a selectable 5V or 7VDC output. The input voltage range of 6 to 28VDC is very flexible and it will not overheat at higher input voltages like the 7805 and other linear regulators may.



- Up to 1A output current at selectable 5V or 7VDC output voltage
- Can also be used for the EtherTen and EtherMega Power-over-Ethernet for efficient switchmode supply remote powering
- Blue power LED
- 0.1" pitch standard header pads

XC-4258 **$19.95**

Getting Started with Arduino Book - 2nd Edition

Now in it's second edition, this book explains what Arduino is, how it works, and what you can do with it. Also includes sections with code and circuit diagrams to get you started on digital input and output, analogue sensors, pulse width modulation output, and communications.

- Softcover 128 pages. 216 x 140mm

BM-7131 **$23.95**

Practical Arduino

A much larger and detailed book. It takes you beyond basics quite quickly and shows you how to make up a typical application /design. This is a necessity as it goes to the heart of Arduino.

- Softcover, 422 pages. 235 x 190mm

BM-7132 **$44.95**

Jaycar electronics
Better. More Technical

NEW AUTOMOTIVE PRODUCTS

LED Decoration Kit for Cars

Designed to adhere along the side skirts of your car for decorative, off-road purposes. Also suitable for car interior applications.

- 12VDC
- LED size: 25(Dia.) x 18(H)mm
- 2 x 1350mm long lengths with 4 LEDs spaced 450mm apart

White *SL-3959* $9.95
Blue *SL-3960* $9.95

NEW $9.95 ea.

LED Light Strip Kits

Pack of 2 x 6 bright LED flexible strip lights for adding extra illumination to your vehicle interior. Just peel off the protective 3M cover and attach to a clean dry surface.

- 12VDC
- Size: 100(L) x 11(W)mm

White *SL-3951* $14.95
Blue *SL-3953* $14.95

NEW $14.95 ea.

LED Flexible Strip Light Kits

Flexible 250mm long strip with 9 x bright LEDs. Adhesive backing makes installation easy. Ideal for lighting under your car, in your engine bay, etc. A mountable on/off switch terminal is included for easier control.

- 12VDC
- Size: 250(L) x 11(W)mm

White *SL-3956* $9.95
Blue *SL-3957* $9.95

NEW $9.95 ea.

4 Door Remote Controlled Central Locking Kit

Remotely lock and unlock your car doors. Install the security button to cut off the fuel pump to prevent the car being stolen. Supplied with 1 master actuator, 3 slave actuators, control relay, two remotes with batteries, kill switch, hardware and wiring loom.

- Working voltage: 9 - 16VDC
- Frequency: 433.92MHz

LR-8842

NEW $79.95

12V Automotive LED Kit

Features a 12 x LED array that can be connected to a T10, BA9s, or 211 base. The 211 base is spring adjustable so it fits a wide variety of car ceiling 211 sockets.

- White
- LED array size: 30(L) x 23(W) x 7(H)mm

ZD-0580

NEW $9.95

Automotive Headlight Reminder Kit

Refer: Silicon Chip August 2001

Nothing is more frustrating than getting into your car early in the morning, only to discover that you had left your headlights on the night before, running your car's battery flat. Features include a modulated alarm, ignition and lights monitoring, optional door switch detection, time-out alarm and a short delay before the alarm sounds. Kit includes quality solder masked PCB with overlay, case with screen printed lid and all electronic components.

- 12VDC
- PCB: 78 x 49 mm

KC-5317

$27.95

3-in-1 Digital Tyre Gauge

Measures tyre pressure in four units (PSI, Bar, Kgf/cm², Kpa) and tyre tread depth to know when it's time to change tyres. Features a large backlit LCD display and blue LED light. See website for full specifications.

- Pocket-sized
- Size: 100(L) x 50(W)mm

QP-2297

NEW $14.95

Digital Map Measure with LED Light

Use this gadget to work out the distance between two points on a map or chart. The scale can be adjusted on each map and can calculate the time required to travel the distance at a given speed.

- Backlit LCD
- Size: 23(L) x 35(H) x 5(W)mm

XC-0374

NEW $9.95

Digital Car Power Adaptor - 3A

Offers 7 different DC voltages with 3A continuous output, plus a USB charging output suitable for the latest Smartphones and i-Gadgets. The display provides accurate digital read outs of vehicle's battery voltage, selected output voltage and power used by the load. LCD features selectable backlight colours.

- Size: 98(L) x 57(W) x 17(H)mm

MP-3673

NEW $69.95

Automotive LED Energy Saving Replacement Globes

A series of energy saving, long lasting SMD LED replacements for cars brake lights, reversing lights, interior ceiling lights, or custom made torches.

ZD-0581

- 12VDC
- White

H1 16 x SMD LED
- Base: H1 • Power: 3.84W
- Size: 69(L) x 24(Dia)mm

ZD-0581 $9.95

ZD-0584

H3 16 x SMD LED
- Base: H3 • Power: 3.84W
- Size: 138(L) x 22(Dia)mm

ZD-0582 $9.95

H4 18 x SMD LED
- Base: H4 • Power: 3.84W
- Size: 69(L) x 47(Dia)mm

ZD-0583 $9.95

H7 18 x SMD LED
- Base: H7 • Power: 3.5W
- Size: 47(L) x 33(Dia)mm

ZD-0584 $9.95

NEW $9.95 ea.

Cup Holder Power Extender

iPhone®/iPod® charger designed to fit inside your cup holder as you drive. Two way cigarette lighter sockets to free up your original socket. Use the USB outputs to charge other devices.

- 2 x USB outputs
- Twist open bottom half
- Size: 100(H) x 70(dia - base) x 92(dia - top)mm

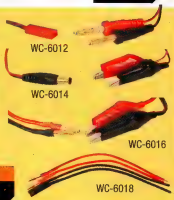
PS-2122

NEW $24.95

Charger Leads for Remote Control Vehicles and Toys

A range of charger, power and test cables with banana plugs, alligator clips and JST connectors commonly used for toys, robotics, models, remote control hobby.

Due early July


WC-6012
WC-6014
WC-6016
WC-6018

JR Transmitter Charger Lead with Alligator Clips
Suitable for use with DC power supplies and charging other DC electronic devices.
- 22AWG PVC wire
- 600(L)mm approx.

WC-6014

NEW $3.95

4mm Banana Plug to Alligator Clip Charger Lead
Used for battery charging applications and powering electronic devices connected to a power source.
- 16AWG silicone wire • 300(L)mm approx.

WC-6016

NEW $4.95

Female JST to 4mm Banana Plug Charger Cable
Commonly used for charging battery packs with JST plugs.
- 22AWG PVC wire
- 600(L)mm approx.

WC-6012

NEW $4.95

2mm Male and Female Gold Connector Charger Lead
Supplied with one red and one black quick connect 2mm wire set. Ideally used in battery packs.
- 20AWG silicone wire • 100(L)mm each approx.

WC-6018

NEW $4.95

To order call 1800 022 888

All savings based on Original RRP. Limited stock on sale items. Prices valid until 23/07/2012.

NEW PRODUCTS

Sine Wave Inverter Petrol Generators

Petrol powered and differ from cheaper units due to the engine drives a DC alternator. The inverter then converts the DC to a stable pure sine wave 230VAC. The added benefit is that the petrol motor is far better matched to the load, reducing overall size, keeping engine speed in line with the load, reducing noise and increasing fuel efficiency. See website for full features and specs.

MG-4204 shown

2kW **MG-4502** $899.00
3kW NEW **MG-4504** $1499.00

NOTE: Not stocked in all stores but our staff can order them in for you.

From $899.00

24V 200W Powertech Monocrystalline Solar Panel

Built and suited to withstand harsh Australian conditions. Covered by a 25 year warranty. See our website for full range and specifications.

- Weight: 15.5kg
- Size: 1580 x 808 x 35mm

ZM-9088

NEW $699.00

Fog Machine with DMX Control

Hook this fog machine up to your DMX512 controller for total customisation on your stage/party effects. Fog can burst with the beats or waft at certain intervals and durations. Creates an unbelievable ambience sure to immerse your audience in the moment.

- Tank capacity: 1.2L
- Remote included
- Size: 335(L) x 150(W) x 186(H)mm

AF-1213

NEW $129.00

1L Fog juice to suit - AF-1212 $17.95

4 Input HDMI Switcher with Audio Return and Ethernet

Connects up to four HDMI devices such as game consoles or DVD players to a single HDMI input. With inbuilt HDCP control, separate audio outputs, an Audio Return Channel (ARC) decoder, and HDMI Ethernet connection you can tie all your devices together without upgrading the whole system.

- HDMI 1.4a Compliant with 3D, HEAC, and CEC support
- HDMI Connections: 4 Inputs, 1 Output
- Audio Output: Optical, Coaxial, 3.5mm Stereo
- Size: 154(W) x 70(D) x 25(H)mm

AC-1619

NEW $99.00

DVI to VGA, Digital to Analogue Signal Converter

Converts digital signal from your video card to an analogue signal suitable for use with your existing VGA display or projector. See website for specifications.

- Supports HDCP 1.2
- Supports analogue video output up to UXGA and 1080p with 10-bit DAC
- Size: 88(L) x 68(W) x 25.5(H)mm

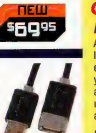
WQ-7445

NEW $59.95

Also available: Analogue VGA to Digital DVI Signal Converter WQ-7446 $59.95

10W Megaphone with Message Recorder

Battery operated and outputs up to 10WRMS. It features a volume control, alarm and whistle function and has a built-in message recorder that allows to play announcements repeatedly. ideal for sporting events, crowd control etc.



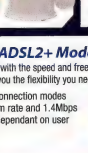
- Shoulder strap
- Light weight and portable
- Requires 8 x AA batteries
- Size: 270 (L) x 162(W) x 235(H)mm

AM-4055

NEW $69.95

UV Sanitiser Toothbrush Holder

Ultraviolet rays sterilise your toothbrushes to stop the build up of potentially harmful bacteria. It helps remove odours and can hold up to 4 toothbrushes at one time.



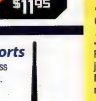
- Size: 235(H) x 115(L) x 90(W)mm

GH-1191

Due early July

NEW $49.95

USB 2.0 Male A to Female A Lead - 3m



- Conforms to USB 2.0 standard - 480Mbps
- 3m length

WC-7703

NEW $11.95

USB 2.0 Male A to Male B Lead 5m WC-7706 $14.95

150Mbps Wireless-N ADSL2+ Modem Router with 4 Ports

Combining 4 x 10/100Mbps LAN ports with the speed and freedom of 802.11n (150Mbps) wireless connectivity, this modem/router gives you the flexibility you need for your home or office network.

- PPPoE, PPPoA, IPoA and bridging connection modes
- Provides up to 24Mbps downstream rate and 1.4Mbps upstream rate (These speeds are dependant on user distance from local exchange)

YN-8317

NEW $69.95

Automatic Universal Laptop Power Supply

A powerful auto-switching laptop power supply with connectors to suit all the major brands including the new HP connector. Features a USB port for charging/powering mobile phones or MP3 players.

- LCD display
- Power output:120W
- Output voltages: 5-24VDC
- Plugs: 13
- Size: 141(L) x 63(W) x 32(H)mm

MP-3328

NEW $129.00

Speakers/Charger with Docking Station for iPhone®/iPod®

Simultaneously charge and sync iPhone®/iPod® via USB. Suitable for use in bedroom, study or on the go.

- Apple licensed product
- Dual 2" full range drivers
- Accepts 4 x AAA batteries for portable use
- Size: 256(W) x 115(H) x 70(D)mm

AR-1889

NOTE: iPod® not included

NEW $69.95

CREE® LED Powered Torch

Features silicone gasket sealed at both ends with a twist switch at the base to prevent accidental engagement. High quality rugged aluminium construction finished in gun metal matte grey/black. Ideal for outdoor activities.

- Light modes: off, high, low
- Burn time: 8 hours (5hrs on max setting)
- Requires 4 x D batteries
- Size: 355(L) x 52(Dia.)mm

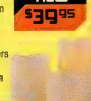
ST-3451 ***Was $99.00***

$79.00 SAVE $20

Christmas in July Gift Ideas!

Motion Activated Lolly Dispenser

A smart alternative to messy, germ-filled lolly bowls and greedy portions. The easy-fill top makes it simple to load in your unwrapped lollies, unsalted nuts and gum balls. Just wave your hand under the dispenser and the perfect amount pours out.



NOTE: Lollies not included

- Built-in sensor
- Large canister storage
- Requires 4 x AA batteries
- Suitable for ages 12+
- Size: 279(H) x 190.5(W) x 165(D)mm

GH-1182

NEW $39.95

3 Piece LED Candle

Features a soft yellow glow that flickers just like a conventional candle would. Made from real wax and comes with a remote control.

- Flameless Technology
- Wireless operation
- Requires 3 x AAA per candle

ST-3927

NEW $24.95

PROJECT ESSENTIALS

20/130W Soldering Iron Starter Kit

All the soldering essentials for the hobbyist. The sum of the individual parts is more than double the price we are selling this kit for. Excellent value!

- Kit contains: 240V 20/130W Turbo soldering iron, spare tip, basic stand, 1mm solder in dispenser tube, metal solder sucker with spare tip and O-ring

TS-1651

$24.95

0 to 30VDC/0 to 3 Amp Regulated Variable Laboratory Power Supply

Provides a stable voltage and current with a regulated output voltage which is adjustable from 0 to 30VDC. Output current is adjustable from 0 to 3 amps. The unit features an uncluttered control panel with LCD, voltage and current adjustment knobs. See our website or catalogue for full specifications.

- Backlit LCD
- Weight: 6.5kg
- Size: 130(W) x 160(H) x 320(D)mm

MP-3086 *Was $199.00*

$179.00
SAVE $20

IP67 True RMS Autoranging CatIV DMM with Wireless USB

A quality true RMS multimeter with a wireless USB computer interface and includes logging software which allows computer based live data whilst keeping your computer completely isolated and protected. Double moulded housing and IP67 rated.

- Non-contact voltage indicator, data hold
- Backlit, auto off
- Diode test and audible continuity
- Cat IV, 600V, 4000 count
- 10A current range
- Size: 170(L) x 79(W) x 50(H)mm

QM-1571

$109.00

Deoxit ProGold Contact Cleaner & Rejuvenator

Simple cleaners wash away dirt, grime, and dust from your expensive equipment but are often ineffective at cleaning tough oxidation and metal sulfide contamination. This product will not only clean, but it will drastically improve equipment performance.

Aerosol NS-1434 $24.95
Kit NS-1436 $24.95

$24.95 ea.

Magnetic Mounting Tape

Simply apply tape to a supporting surface and another piece to the item, then stick it anywhere you like. Ideal for craft projects, calendars, kids' artwork or to-do lists.

- One side magnetic, one side adhesive
- Residue-free
- Easy tear-off, no scissors
- 3m x 12mm roll

LM-1608 *Was $9.95*

$5.95
SAVE $4

Ultrasonic Distance Meter with Laser

Measures distance, calculates area, sums total readings and stores data for later use in imperial or metric units. Feature a laser pointer for accurate placement of the measurement point.

- Backlit LCD
- Auto or manual power-off
- Case and belt-clip included
- Size: 175(L) x 62(W) x 45(D)mm

QP-2295 *Was $44.95*

$29.95
SAVE $15

LED Screwdriver with 10 Bits

The handle has four built-in LEDs to provide working light. 10 bits are included, but any standard hex bit will fit.

- Bits included: PH #0, #1, #2, slotted 3, 4, 5mm, T15, M6 pin drive, M4 hex, hex - 1/4" square converter
- Batteries included, plus a spare set

TD-2091 *Was $22.95*

$14.95
SAVE $8

Pro-Style Pen DMM

This precision instrument is made using double moulding techniques to make it tough enough to be used every day. It features a spot to put the probe guard when in use and contains 7 functions in the one unit.

- Pen style
- 4000 count
- Cat III 600V
- Diode test, data hold
- Size: 230 (L) x 35(W) x 20(D)mm

QM-1498 *Was $49.95*

$39.95
SAVE $10

3/8" Precision Keyless Drill Chuck

Replace that cheap and inaccurate drill chuck on your cordless drill with this precision keyless model. Features an ergonomic design and a patented 'Click Lock' system to indicate that the chuck is properly locked.

- 3/8" - 24UNF mounting thread
- 1/32" - 3/8" (0.8 - 10mm) drill capacity
- Suitable for drills up to 1,200 watts

TD-2011 *Was $23.95*

$14.95
SAVE $9

Solder Paste SMD Syringe

Ideal for surface mount work and rework. Easy application, simply apply it to the soldering pads, put your components in place and heat it with your soldering iron.

- 15g
- Size: 120 (L) x 15(Dia.)mm

NS-3046

$12.95

Transistor Tester

Refer: Electronics Australia September 1983

Have you ever unsoldered a suspect transistor only to find that it checks OK? Troubleshooting exercises are often hindered by this type of false alarm. You can avoid these hassles with the In-Circuit Transistor, SCR and Diode Tester. The kit does just that, test drives WITHOUT the need to unsolder them from the circuit! VERY HANDY!

- Kit includes a Jiffy box, battery and electronic components and panel showing truth table for device checking

KA-1119

$27.95

Stainless Steel Tweezer Set

A set of four tweezers, three supplied with vinyl handles.

- 115mm length approx.

TH-1752

$8.95

Polyurethane Potting Compound

Composed of a polyurethane base designed to electrically insulate and protect against dust and moisture.

- Allow 15 minutes for setting time
- Cures in around 4-5 hours
- 70ml

NM-2016

$9.95

Illuminated Gooseneck Magnifier

This hobbyist's magnifier has a 2 x main magnifier lens with 5 x insert lens and 2 LED lights, all mounted on a flexible arm. Can be free-standing or clamped to a surface up to 38mm thick. Comes with a soft protective pouch for your lens to protect it from dirt and dust.

- Lens 110mm (Dia.)
- Stands 225mm high
- Requires 3 x AAA batteries (use SB-2413)

QM-3532

$29.95

10MHz Velleman Rechargeable Handheld Pocket Scope

A complete portable oscilloscope with a tiny size. Aside from standard scope features, it has nifty tools for measurement of RMS speaker power, display hold function, and memory storage for 2 signals. Housed in a durable rubber surround with backlit LCD display and inbuilt Ni-MH battery. See our website or in-store for full specifications.

- 10MHz
- Rechargeable
- CRO probe and USB charge cable supplied
- Size: 114(H) x 74(W) x 29(D)mm

QC-1914

$249.00

To order call 1800 022 888

All savings based on Original RRP. Limited stock on sale items. Prices valid until 23/07/2012.

Knobs

Brushed Aluminium
Ideal for Hi-Fi projects. Suits 0.25"/6.35mm shaft.

Silver 16 x 14	*HK-7020*	$2.75
Silver 22 x 14	*HK-7022*	$2.95

From $2.75

Black Anodised Aluminium
Grub screw fixing.
Suit 0.25"/6.35mm shaft.

Black 16 x 14	*HK-7009*	$2.75
Black 22 x 14	*HK-7010*	$2.95
Black 29 x 14	*HK-7011*	$3.95

From $2.75

Black Plastic with Aluminium Insert
White pointers - brass insert.
Grub screw fixing. Suit 0.25"/6.35mm shaft.

From $1.50

Silver/Black 20 x 18	*HK-7786*	$2.20
Silver/Black 27 x 15	*HK-7740*	$1.50
Silver/Black 34 x 17	*HK-7741*	$1.85
Silver/Black 45 x 20	*HK-7742*	$3.45

Jiffy Boxes

Manufactured from ABS plastic and designed to incorporate our customers wanted in a constructor's box. Sizes are compliant with industry standards externally and PCB fitting internally.

- Supplied with lid fixing screws and safety concealment plugs

15% OFF JIFFY BOXES!

				Was	*Now*	*Save*
UB1	*Black*	*158 x 95 x 53*	*HB-6011*	$4.45	$3.78	$0.67
UB2	*Black*	*197 x 113 x 63*	*HB-6012*	$6.95	$5.91	$1.04
UB3	*Black*	*130 x 68 x 44*	*HB-6013*	$3.95	$3.36	$0.59
UB3	*Grey*	*130 x 68 x 44*	*HB-6023*	$3.95	$3.36	$0.59
UB5	*Black*	*83 x 54 x 31*	*HB-6015*	$2.95	$2.51	$0.44
UB5	*Grey*	*83 x 54 x 31*	*HB-6025*	$2.95	$2.51	$0.44
UB5	*Clear*	*83 x 54 x 31*	*HB-6005*	$2.95	$2.51	$0.44
UB5	*Blue*	*83 x 54 x 31*	*HB-6004*	$3.45	$2.93	$0.52

From $2.51

BLUE (TRANSLUCENT IMAC® LOOK)

IC

74HC IC

74HC107 14pin Dual JK Flip-Flop +Clear
ZC-4837 $2.25

Linear ICs

LM6482AIN Dual CMOS op-amp
ZL-3482 $4.95

LM6484AIN Quad CMOS op-amp
ZL-3484 $6.95

NEW From $2.25

Miniature Nylon MOLEX-Type Connectors

Suitable for high current/high density, wire-to-wire or wire-to-board applications for both power and signal connections.

- Fully isolated terminals
- Positive housing locks
- Four point of contact for reliability
- Low engagement force terminals

NEW From $2.75

2 Pin PP-2021	$2.75
3 Pin PP-2023	$2.95
4 Pin PP-2027	$3.45
6 Pin PP-2025	$3.95

SMD Optocouplers

NEW TLP113 SOIC8 (ZD-1941)

4N25S	*PK10*	*ZD-1926*	$9.95
4N35S	*PK10*	*ZD-1934*	$8.95
6N137S	*PK10*	*ZD-1938*	$24.95
6N138S	*PK10*	*ZD-1943*	$24.95
TLP113	*Ea.*	*ZD-1941*	$5.35

NEW From $5.35

SMD

Large 7-Segment Display

58mm high, ideal for house numbers, clocks etc.

- Red LED display

ZD-1850 *Was $13.95*

$9.95
SAVE $4

Dual N-Channel 30V MOSFET

Used in many projects such as DC-DC conversion and switching circuits.

- Si4944DY type
- SOIC8 case

ZK-8821

NEW $4.30

Transistors

- 200W
- TO-264

NJL3281D NPN ZT-2236 $8.25
NJL1302D PNP ZT-2237 $8.25

NEW $8.25 ea.

Switching Voltage Regulators

LM2678T-5.0	*TO-220*	*+5V 5A*
ZV-1636	$14.95	
LM2678T-12	*TO-220*	*+12V 5A*
ZV-1637	$14.95	
LM2678T-ADJ	*TO-220*	*+1.2 to +37V 5A*
ZV-1638	$14.95	
TL499ACP	*DIP-8*	*+2.9 to +30V 100mA*
ZV-1644	$3.50	

NEW From $3.50

Low Dropout Regulators

Due early July

From $1.45

LP2950ACZ-5.0	*TO-92*	*+5V*	*100mA*
ZV-1645	$1.45		
LM2936-3.3	*TO-92*	*+3.3V*	*50mA*
ZV-1650	$3.85		
LM2936-5.0	*TO-92*	*+5V*	*50mA*
ZV-1652	$3.85		
LP2951ACN	*DIP8*	*+1.24 to +29V*	*100mA*
ZV-1562	$7.55		
REG103-A	*SOT-23*	*+1.3V to +5.5V*	*500mA*
ZV-1654	$10.45		
MCP1703T-5002E/CB	*SOT-23*	*+5V*	*500mA*
ZV-1545	$19.95		

See website for specifications & datasheets for all components.

Diodes

1N5711 Schottky 70V 15mA
ZR-1027 $0.60

1N5822BP Schottky 40V 3A DO-201
ZR-1048 $0.95

MBR735 Schottky 35V 7A TO-220
ZR-1029 $1.50

NEW From 60c

Switches

DPDT Toggle Switch
This switch will handle mains power switching.

- Rated 250VAC @10A

ST-0575

$4.95

IP56 Round Pushbutton Switch

- QC spade lugs • 20mm dia. hole
- 250VAC

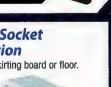
DPST 6A	*Black*
SP-0743	$5.95
SPST 1.5A	*Red Illuminated*
SP-0744	$6.95

From $5.95

DPST Rocker Switch Mini

- DPST 240V @ 6A
- Red illuminated actuator with on/off indicator
- Solder terminals

SK-0995


$4.95

Professional 500A Battery Isolation Switch

A high grade, high quality and very high current rated battery isolation switch for high power applications. Features heavy gauge M12 brass bolt terminals, cast metal body for extra strength and durability. Supplied with a right angle mounting bracket.

- Continuous rating (6-48VDC): 500A
- Max rating (6-48VDC): 2000A (10 sec.)
- Size: 70(D) x 100(H)mm

SF-2247

NEW $49.95

75 Ohm TV Floor Socket with F59 Connection

Designed to mount on the skirting board or floor.

- PAL socket output
- F59 connection at rear
- Mounting screws
- Size: 50(L) x 30(W) x 25(H)mm

LT-3063

NEW $3.95

PROJECT KITS FOR KIDS

Solar Educational Kits

Keep kids occupied for hours and learn about solar technology by constructing any of these project kits. No tools, soldering or glue required. Can also be powered by the light from a household 50W halogen light.

- Detailed instruction manual included

6-in-1 Solar Kit

- Projects: windmill, car, dog, plane, airboat, revolving plane
- Suitable for ages 10+
- Solar panel size: 25(L) x 30(W) x 10(H)mm

KJ-8926 ***Was $19.95***

$11.95 SAVE $8

8-in-1 Solar Kit

- Projects: car, riverboat, octopus, spaceship, solar LED, robot, windmill, space alien
- Suitable for ages 8+
- Solar panel size: 60(L) x 35(W)mm

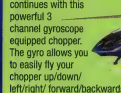
KJ-8925 ***Was $34.95***

$29.95 SAVE $5

Christmas in July Gift Ideas!

3 Channel Double Blade RC Helicopter with Gyroscope

The defiance of gravity continues with this powerful 3 channel gyroscope equipped chopper. The gyro allows you to easily fly your chopper up/down/ left/right/ forward/backwards.



- Remote requires 4 x AA batteries
- 70min charge time gives about 6-8min flight time
- Suitable for ages 8+
- Size: 450(L) x 83(W) x 200(H)mm

GT-3530

NEW **$69.95**

3 Channel Single Blade RC Helicopter with Video Recording

Capture the thrills and spills of your aerial stunts with this highly manoeuvrable single blade chopper. Equipped with a gyroscope, 3 channels and pack with natural speed and performance that single blade choppers offer.

- 1G MicroSD card included
- 2-3hrs charge time gives about 8min flight time
- Video capture: 640 x 480 at 30fps
- Suitable for ages 14+
- Remote requires 4 x AA batteries
- Size: 495(L) x 65(W) x 14(H)mm

GT-3562

NEW **$99.00**

Solar Powered Robot Kit

Build your own solar powered robot with this kit. Supplied with a hand cranked dynamo for alternative power source. Robot moves forward and reverse. Hours of robotic fun.

$9.95 SAVE $20

- No batteries needed
- Suitable for ages 8+

KJ-8821 ***Was $29.95***

Salt Water Fuel Cell Engine Car Kit

VIDEO

This kit demonstrates the concept of a salt powered automotive engine. It gives the next generation a look at alternative means of propelling cars of the future. Assemble, add salt water, and your 4WD car will be propelled forward!

- Assembly time: 3 hours
- Suitable for ages 8+
- Size: 120(L) x 100(W) x 91(H)mm

KJ-8960

$24.95

Campbelltown Store Relocation

2/4 Rose St (Cnr of Rose St & Blaxland Rd) NSW 2560
Ph: (02) 4620 7155

Plenty of parking available! ***July 2012. Check website for exact opening date.***

Science Educational Kits

A collection of 4 DIY educational science kits that provides useful knowledge on simple physics concepts.

- Suitable for ages 8+
- 15mins assembly
- Box size: 140(L) x 140(W) x 70(H)mm

Flying Disc Kit

Show the concept of rotary motion and how it can be used to lift an object into the air. In this kit a small plastic disc resembling the blade of a helicopter will become airborne once enough rotary speed is applied to it.

NEW **$9.95**

- Requires 2 x AA batteries

KJ-8944

Electronic Circuit Maze Challenge Kit

Assemble the kit and try to guide the metal hook around the wire maze. If the hook touches the wire it will cause electric current to flow, thus triggering a bell to ring.

NEW **$9.95**

- Requires 2 x AA batteries

KJ-8946

Aim and Shoot Kit

Learn about energy conversion with a basketball backboard plus hoop with a little launcher to shoot the basketball into the hoop. The motors rotational energy is converted to left/right energy so the basketball hoop sways back and forth.

NEW **$9.95**

- Requires 1 x AA batteries

KJ-8948

Amazing Soccer Fever Kit

Consists of a goal keeper which guards the goal and a little plastic foot to kick the ball. Try and make it past the keeper!

NEW **$9.95**

- Requires 1 x AA batteries

KJ-8949

YOUR LOCAL JAYCAR STORE – Free Call Orders: 1800 022 888

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Tuggerah **NEW** Ph (02) 4353 5016
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Wagga Wagga Ph (02) 6931 9233
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Arrival dates of new products in this flyer were confirmed at the time of print. Occasionally these dates change unexpectedly. Please ring your local store to check stock details. **Prices valid from 24th June to 23rd July 2012.**

HEAD OFFICE
320 Victoria Road, Rydalmere NSW 2116
Ph: (02) 8832 3100 Fax: (02) 8832 3169

ONLINE ORDERS
Website: www.jaycar.com.au
Email: techstore@jaycar.com.au

Jaycar electronics
Better, More Technical

PRODUCT SHOWCASE

Altronics "universal" A/V & computer cable checker

If you're involved in electronics/audio/computers/etc, over the years you tend to amass a collection of cables and leads which typically end up in a box "in case you never need them!"

The problem is that when you do need a cable, even if you can lay your hands on it, you have no idea if it is good or faulty.

And that applies even more so to installers, roadies, etc (even if their leads are likely to be a bit better organised).

Cables do suffer damage, often hidden – and if you rely on appearance the chances are you're going to be caught out when you can least afford it!

That's where this neat Cable Tester from Altronics (cat Q2022) can come in really handy. You simply plug your lead into the appropriate sockets and rotate the switch to show which pins are connected to each other.

It will test leads with 6.35mm jacks, 3/5/7/8 pin DIN, RCA, 3/5 pin XLR, 4P and 8P Speakon, banana plugs, RJ45 and USB – and the leads can have combinations of plugs, too. For example, you might have an XLR to stereo 6.35mm jack lead – no problem!

One disappointment was the lack of a 3.5mm socket – 3.5mm leads are becoming very common for use with consumer and computer equipment.

It's housed in a steel case, built to withstand the rigours of professional use.

Normally $57.95, it's currently on special at just $34.95. Even at full price, it's a bargain! Available through all Altronics stores, dealers and webstore.

Contact:
Altronic Distributors Pty Ltd
PO Box 8350, Perth Busn Centre, WA 6849
Tel: 1300 780 999 **Fax:** 1300 790 999
Website: www.altronics.com.au

New mikroC, mikroBASIC and mikroPascal compilers from MikroElectronika

New versions of mikroC, mikroBASIC and mikroPascal compilers for ARM now include support for 186 new microcontrollers from STMicro, including Cortex-M3 and Cortex-M4, with over 50 libraries and dozens of examples to get you started in no time.

If you already own compiler licenses can get double the utility by just downloading the new compiler version. Those who don't can evaluate the compilers under Demo limit and explore the look and feel first.

EasyMx PRO v7 development board for STM32 supports the entire family of STM32 microcontrollers and it's replete with modules.

An on-board mikroProg debugger based on ST-LINK v2 will provide fast debugging and programming interface.

It comes with an EasyTFT board which carries a 320 x 240 pixel TFT touchscreen which can also be used to attach a standard GLCD of 128 x 64 pixels.

Two mikroBUS sockets enable you to use fast growing number of popular Click Boards.

Two new mikromedia STM32 development boards are also available. The M3 version uses a STM32F207VGT6 and the M4 version has a STM-32F407VGT6 device.

Both are equipped with rich multimedia modules, and provided with full set of examples and documentation.

The mikroProg programmer/debugger for STM32 costs just $49.

Contact:
mikroElectronika
Višegradska 1A, 11000 Belgrade, Europe
Tel: (0011) 381 11 366 0600
Fax: (0011) 381 11 366 0601
Website: www.mikroe.com

Cleansui Water Filters from Verbatim

Verbatim Australia, well known for their storage products and LED lighting have expanded their product offering to Water Filter products.

Verbatim's parent company Mitsubishi and subsequent sub-brand Mitsubishi Rayon are the manufacturers of Cleansui premium water filter products with filtration levels of down to .01 micron.

This is achieved through the use of a patented hollow fibre membrane which removes bacteria and other nasties that other water filters that use only an activated carbon filter can leave behind.

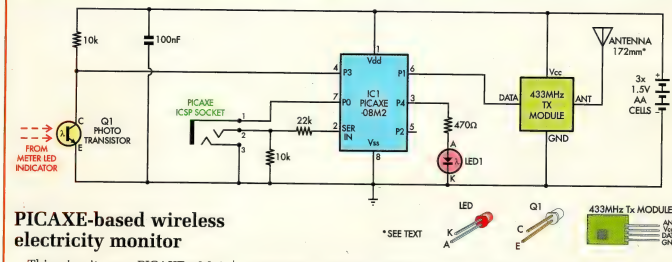
The Cleansui range has a product for every use including portable filter jugs, on-tap systems, under sink systems and commercial filters.

To find out more about Cleansui visit www.cleansui.com.au

Contact:
Verbatim Australia
6 Weir St, Glen Iris, Vic 3146
Tel: (03) 9823 0999 **Fax:** (03) 9824 7011
Website: www.verbatim.com.au

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



PICAXE-based wireless electricity monitor

This circuit uses PICAXE08M2 microcontrollers and low cost 433MHz ASK transmitter and receiver modules to provide a wireless link between the meter box and a remote display inside the house.

Modern (electronic) watt-hour meters have a LED indicator that usually pulses at a rate of 1000 times per kilowatt-hour (kWh), ie, once per watt-hour. A phototransistor is positioned in front of the LED and a PICAXE08M2 (IC1) calculates the time between flashes, using the pause function and interrupt capability of the chip; an interrupt is generated each time input P3 goes low.

The duration in tens of milliseconds is calculated and is transmitted using a 433MHz ASK transmitter (Jaycar ZW3100 or similar), along with a station identifier to ensure that the receiver does not respond to other transmitters. Each transmit packet is indicated by a single flash from LED1. (A light dependent resistor may also be used if a suitable phototransistor cannot be easily obtained).

The receiver comprises a 433MHz module (Jaycar ZW3102 or similar) that feeds the pulse data to a PICAXE08M (IC2). The average power, corresponding to the interval measurement, is calculated by dividing 3600 (the number of seconds in an hour) by the time between pulses in seconds; one second between pulses = 3600W; 10 seconds = 360W etc.

The calculated values in kWh, watts and the pulse time are displayed on a standard 16-character by 2-line LCD (Jaycar QP5517 or Futurlec LCD 16x2). IC3, an 8-bit I^2C port expander (available from Futurlec), is used to provide sufficient outputs for the PICAXE08M2 to drive the LCD display. The three address lines of the port expander (A0, A1 & A2) are tied to the +5V line. Two 4.7kΩ pull-up resistors are provided for the I^2C clock and data lines. LED2 flashes whenever a data packet is received.

For testing and timing calibration purposes, a third PICAXE08M2 was configured to provide pulses from one to 50 seconds in 0.5-second increments into pin 3 of the meter box transmitter module. Adjusting the pause routine and making some allowances for the transmit time has provided a reasonably accurate result. For example, resolution is about 6W for readings of 3600W, changing to better than 1W for readings below 360W.

Power for the meter box unit is derived from three 1.5V alkaline AA cells while a regulated 5V DC plugpack supplies the receiver module.

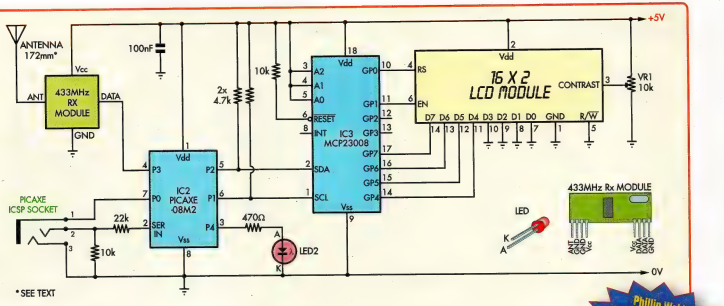
The resistors associated with the 3.5mm stereo socket in each circuit provide the standard PICAXE programming interface.

Because the metal meter box is an effective shield, a short antenna for the transmitter module is inadequate. To obtain adequate range, an external antenna was used, comprising a 2.5m length of coax cable with the screen stripped for about 170mm at the far end. The core insulation was left in place and the open screen end was covered with a small heatshrink sleeve. To hold the antenna up, a used hard disk drive magnet was strapped to the base of the antenna with a cable tie and this was then attached to the top rail of a nearby steel fence.

The phototransistor was secured with a bracket made from a small piece of thermoplastic that hooks over the meter body. A small blob of Blu-Tack® helps to keep it in place. The bracket should not obscure the meter's LCD or the optical in/out port and care must be taken so as to not disturb any of the electrical equipment in the meter box.

During the development of this project, it was apparent that an increase in load could cause the monitor to show a lower power reading. It was soon realised that my rooftop solar system was generating at the time and the mains meter pulse does not distinguish between import or export power (the metering is a net arrangement).

Under these conditions, a small



increase in demand will reduce the exported energy. A large increase in demand can invert the export to import. The inability of this monitor to determine power flow direction is a drawback, however it is possible to identify individual appliance loading by switching the item off or on for a short period and observing the meter monitor.

Of particular interest is that I found that the minimum background load overnight was around 100W (refrigerator not running). This was due to numerous items still operating or on standby, including TVs, personal video recorder, USB hard drives, bedside clocks, night light, broadband modem, wireless router, network attached storage, fire detectors, microwave and wall oven clocks, electric garage door and watering system transformers. These background loads are operating continuously, with an estimated annual cost of over $200.

Phillip Webb,
Hope Valley, SA.

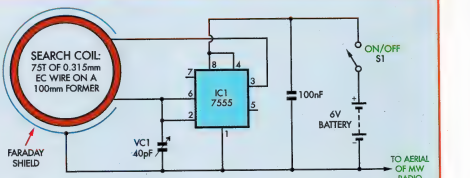
Phillip Webb is this month's winner of a $150 gift voucher from Hare & Forbes

A really simple metal detector

Metal detectors don't come any simpler than this circuit. It will detect a 25mm-diameter coin at a distance of 150mm or a large metallic object at a distance of up to 500mm in free air.

As shown, it's based on a 75-turn search coil and a 7555 CMOS timer (IC1). IC1 is wired in astable mode and its frequency is set to somewhere in the AM band by the impedances of the search coil and trimmer capacitor VC1. The resulting RF signal and its harmonics are then detected by an AM radio with its antenna attached to the circuit ground (0V) via a lead.

The search coil is made by winding 75 turns of 0.315mm-diameter (30SWG) enamelled copper wire around a 100mm-diameter former (eg, PVC pipe). The completed loop is then removed from the former and firmly taped all around with insulating tape. A Faraday shield is then made by wrapping narrow strips of aluminium around it. Make sure that the shield has a 10mm gap at one point, so as not to make a shorted turn.



A short length of wire should then be connected to one end of the shield, after which it should be further wrapped in insulating tape.

The coil can then be attached to a non-metallic baseplate (eg, plywood) and connected to the circuit using microphone cable. The shield wire of the coil is connected to the 0V (ground) rail of the circuit using the cable's shield.

Once the assembly is complete, place an AM radio near the coil (about 250mm away), connect the circuit ground to the radio's antenna and switch on. By tuning the radio, you should hear squeals (harmonics) in different parts of the band. Choose a harmonic that comes in loud and clear.

Now pass a metallic object over the coil. The tone should be shifted in frequency, either upward or downward, depending on the type of metal. Adjust VC1 for maximum sensitivity.

Mahmood Alimohammadi,
Tehran, Iran. ($45)

Modifying an urn to save power

Because of the excessive amount of time involved in tea breaks in the SILICON CHIP office, the Publisher wanted to streamline the process somewhat while still grudgingly acknowledging that the occasional cups of tea and coffee were probably permissible. Hence we recently purchased an 8-litre urn but the Publisher soon noticed that although it had an adjustable thermostat, it continuously boiled the water regardless of the temperature setting. He was not happy!

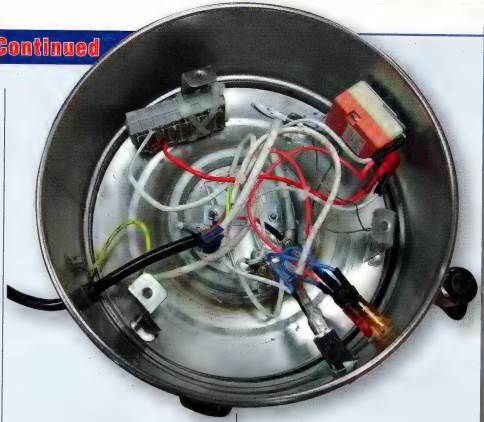
It uses a 2kW element to bring the water up to the set temperature and a 175W element/thermal fuse to keep it at that point. But 175W is much more than necessary to keep the water at boiling point and most of this power is wasted.

We decided to reduce the standing power to less than 50W, which should be sufficient to keep the water close to its boiling point. This was achieved by connecting a capacitor bank in series with the smaller element, to reduce the voltage across it. We originally used eight 470nF 250VAC X2-rated capacitors wired in parallel.

The nominal capacitance is 8 x 470nF = 3.76μF but we measured 3.3μF, our capacitors being somewhat under their specified value. The impedance of this capacitor bank at 50Hz is $1 \div (2\pi \times 50\text{Hz} \times 3.3\mu\text{F}) = 964\Omega$.

We also measured the element resistances, which are 27Ω for the main (2000W) element and 270Ω for the smaller element. These are in series in keep-warm mode, giving around 300Ω total. We can then calculate the impedance of the urn as a whole (elements plus series capacitors) as $\sqrt{(300\Omega^2 + 964\Omega^2)} = 1010\Omega$.

Without the capacitors, the unit draws 230VAC/300Ω = 766mA in keep-warm mode, which gives us the 175W figure (0.766A x 230VAC). With the capacitors in circuit, this is reduced to 230VAC/1010Ω = 228mA, giving us a power of $0.228\text{A}^2 \times 300\Omega = 15.6\text{W}$. We measured around 18W but this also includes the current for the neon lamp.



Note that if you simply multiply the current draw (228mA) by 230VAC, you get a figure of 52.5W. This is correct but it represents both the 15.6W of real power and 36.9W of "imaginary" power. This extra energy is required to charge and discharge the capacitor bank on each mains cycle but this energy is returned to the AC mains supply and not consumed by the urn.

For this reason, the relationship between the capacitance added and the resulting power consumption is not linear. If we add two more capacitors, giving us (say) 4.13μF, the current goes up to 278mA and the power to 23W; a 50% increase in power from a 25% increase in capacitance.

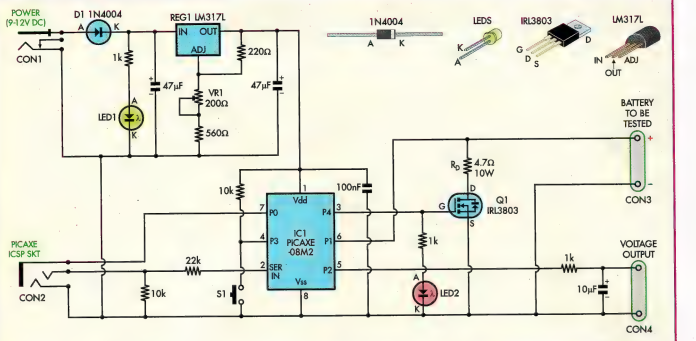
Having reduced the keep-warm mode power to 15.6W (around 10% of the original), we found the water was maintained at around 97°C. Since this is below boiling point, the main element occasionally kicked in to re-boil the water. We subsequently decided to install the extra two capacitors after all, to keep the water closer to boiling point.

The 10 x 470nF X2 capacitors cost less than $20. If the urn is on for 10 hours a day, 250 days a year, this modification reduces its power consumption by 10h x 250d x (0.175kW – 0.023kW) = 380kWh/year. At 30c/kWh, that's a saving of about $114 per year. This modification pays for itself in just a few months and keeps the Publisher happy.

There are other ways to achieve similar results. Had we connected a 1000V, 3A diode in series with the keep-warm element, that would have halved its power consumption as the element would only conduct for half of each mains cycle. However, we would not recommend doing this for continuous use because of the risk of corrosion in the wiring due to DC current.

Alternatively, we could have just disconnected the smaller element entirely. The urn would have then cycled the main element on and off to keep the water hot. However that would allow the water temperature to vary more and would have also worn out the thermostat contacts faster.

The above photo shows how the capacitors were installed. We ran a large cable tie around them and then soldered tinned copper wire along the leads (which were already cut short). This assembly was then cable-tied to one of the mounting brackets in the base of the urn. We cut the wire between the thermostat and small element and soldered the



Capacity test circuit for rechargeable cells

As rechargeable cells get older, their capacity declines. This decline is related to the number, depth and rate of discharge and recharge cycles.

Knowing the available capacity is useful so that you don't get caught with dodgy cells. It also allows you to match cells when they are used in series. Most inexpensive brands also benefit from testing, as their rated capacity sometimes doesn't match reality.

This simple circuit allows you to test cell capacity by discharging the cell at a set rate (as determined by R_D). In practice, R_D is normally chosen to set the discharge current to between C/3 and C/7. For cells rated up to about 2500mAh, a 4.7Ω 10W resistor can be used which sets the discharge rate to about 1.2V ÷ 4.7Ω = 250mA which is C/10 for a 2500mAh cell.

Alternatively, if you have a demanding application for your cells, testing them at a discharge rate that's equivalent to the normal current drain makes good sense.

The PICAXE (IC1) controls everything. It detects when a cell is connected to the circuit (via CON3) and switches its P4 port (pin 3) high to turn on N-channel Mosfet Q1, starting the discharge. This terminates when the cell voltage drops to 1V. LED1 lights while the cell is discharging and goes out when the end-point is reached.

The PICAXE provides a running total of the measured capacity via the serial programming port (4800,8,1,N) at CON2. It also provides a proportional DC voltage on CON4 of 1V per Ah of capacity measured. In addition, the PICAXE stores the result of the completed test so it can run without a PC or meter permanently connected.

The result of the last test is recalled and output as both serial data and a PWM voltage the next time the circuit is turned on. The serial data for the last test can also be retrieved at any time by pressing S1.

To read the data, it's necessary to connect the ICSP socket (CON2) to a PC via a PICAXE download cable. You can either use a 3.5mm stereo jack to USB serial adaptor (**www.picaxe.com/Hardware/Cables/PICAXE-USB-Download-Cable/**) or a 3.5mm stereo jack to serial D socket (**www.picaxe.com/Hardware/Cables/Serial-9-way-D-Download-Cable/**) if the PC has a serial socket. You will also need to grab a freeware terminal program, eg, Tera Term from **http://logmett.com/index.php?/download/tera-term-474-freeware.html** or PuTTY from **www.chiark.greenend.org.uk/~sgtatham/putty/**

The accuracy of the circuit is limited by the accuracy of the PICAXE's internal oscillator to around 2%. It's also necessary to use a IRL3803 logic-level FET with a very low on-resistance and to set the supply voltage from REG1 to 5.12V using VR1. Power can come from an external 9-12V DC source, with diode D1 providing reverse polarity protection.

If accuracy isn't important, you could use a standard 5V regulator and a cheaper Mosfet (even a 2N2700 if the current is below 200mA).

The IRL3803 is available from RS Components, element14 and Futurlec. Its on-resistance is just 6mΩ and it can handle around 10A without needing a heatsink.

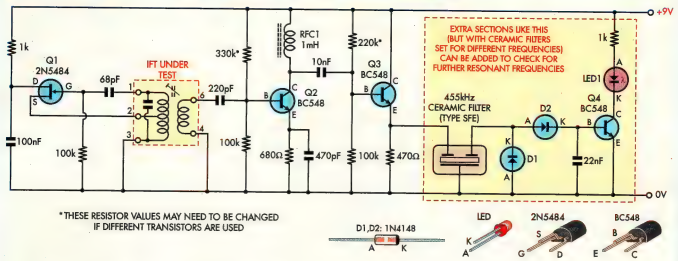
Finally, the software (rechargeable.bas) can be downloaded from the Silicon Chip website.

David Eather,
Toowoomba, Qld. ($60)

capacitors in series.

It's important to use heavy-duty, mains-rated wire and to add cable ties to keep the wires away from the main element. We were also careful to ensure that the capacitor leads and exposed wiring can't come in contact with the chassis and that there is at least 2.5mm between the chassis and any exposed mains conductors, to prevent flash-over.

Silicon Chip.



*THESE RESISTOR VALUES MAY NEED TO BE CHANGED IF DIFFERENT TRANSISTORS ARE USED

Checking IF coil frequency

If you need to check the operation and tuning of intermediate frequency (IF) coils, this circuit will enable you to do it. It eliminates the need for a frequency counter and will indicate whether the operating frequency is high, low or correct.

One possible application could involve construction of the Theremin featured in the March 2009 issue of SILICON CHIP. That circuit employs two IF coils operating at around 450kHz and this checker circuit will let you quickly select good coils from an assortment of unmarked units.

The IF coil to be tested (IFT) is connected to JFET Q1, in the same configuration as the reference oscillator from the abovementioned Theremin. The secondary of the IF coil then drives the base of NPN transistor Q2 which is configured as a common-emitter amplifier.

Q2's collector output drives NPN transistor Q3 which operates as an emitter-follower to buffer the signal before passing it to a 455kHz ceramic filter which has a very narrow pass-band (centred on 455kHz). The output signal from the ceramic filter is fed to a diode pump circuit comprising diodes D1 & D2 and the 22nF capacitor.

When the oscillator's operating frequency is centred on 455kHz, the diode pump will develop sufficient voltage to turn on transistor Q4 and the associated red LED.

Tweaking the slug of the coil until the LED lights ensures that it is set for operation at 455kHz in the Theremin circuit.

Ceramic filters are available in a wide range of frequencies, eg, 450kHz, 455kHz, 4.5MHz, 5MHz, 5.5MHz, 5.74MHz (TV sound IF), 6MHz and 10.7MHz (FM IF) so this circuit is also applicable to those frequencies.

John Russell,
Bangkok, Thailand. ($50)

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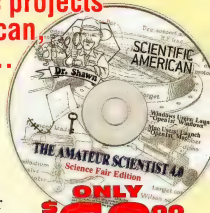

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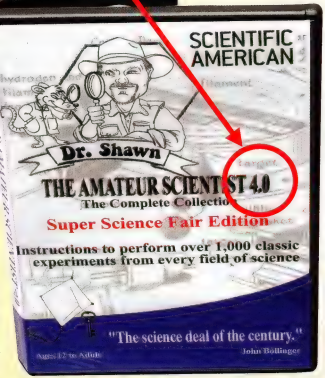

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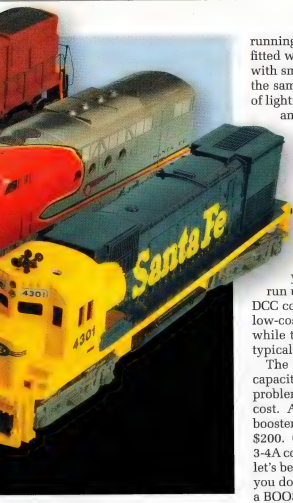
10A DCC booster for model railways

Most DCC base stations have puny current capabilities which are exposed if you want to run more than a few locos and peripherals on your model railway layout. Problem is, DCC boosters are expensive, with a well-known 5A booster costing over $200. Problem no longer; build this 10A beauty at a fraction of the cost.

IF YOU ARE a model railway enthusiast you probably already know about the current trends in model railways, with Digital Command Control or DCC being the standard control system of today. A beginner's guide to the DCC standard was published in the February 2012 issue of SILICON CHIP.

The advantage of DCC is that many model trains can be run on the same layout at the same time and all under individual control. In fact, many of the DCC systems available today can control or address up to 9999 trains and peripherals at the same time.

Apart from being able to address so many locos and peripherals, DCC greatly simplifies the wiring to model railways. There is no need to have umpteen hundreds of wires going to points, lights, track blocks etc. Since the whole system can be regarded as a serial bus (much like Ethernet or USB), you need only connect a pair of wires



to every device and the individually-addressable DCC decoders take care of everything.

Given that a DCC system can handle such a huge number of model locomotives and other equipment, you might wonder how much current a typical system needs to deliver. The current requirement for DCC locos varies wildly. If the loco is large, with a sound decoder and a smoke generator (in the case of a steam loco), then the current required may be 1A or more. On the other hand, a small shunting loco may require less than 200mA. All of which makes it difficult to calculate the current requirements of any layout.

To give an extreme example, on a recent trip to a large model train layout the author noticed that the layout used a huge power supply. I asked the club techo and he said it was an 18V DC power supply capable of supplying 60A; that's 1080 watts! The supply was fitted with voltage and current meters. At the time, the current meter was showing the total layout load to be 32A.

I was a bit shocked at this but was informed that the DCC system was running more than 25 locomotives, all fitted with sound decoders and some with smoke, right at that moment. At the same time, it was powering a lot of lighting with in excess of 80 lamps and signal LEDs. As well, all the point decoders were powered from the DCC system.

Incidentally, he told me that the power supply often runs for hours at this level yet uses only two small computer fans for cooling. That's what I call design efficiency!

But even if you're not running a large DCC layout you will quickly find that you run up against the limits of typical DCC command (base) stations. Some low-cost systems can only supply 1A while the higher priced systems can typically supply 3-4A.

The only way to get more current capacity is to add a DCC booster. The problem with most boosters is the cost. A well-known brand of DCC booster supplying 5A costs around $200. Other boosters rated at only 3-4A cost well over the $100 mark. But let's be serious, if you want a booster, you don't want a flyweight; you want a BOOSTER!

The booster presented here can supply up to 10A and you can build it for a fraction of the cost of commercial boosters. It has been tested on several brands of DCC system and it operated without any problems. It is fully compatible with NMRA (National Model Railway Association) standards for DCC systems and so should operate with all systems that conform to the NMRA standards. Incidentally, you can view these standards and many more on the NMRA web site: **www.nmra.org**

As presented, our DCC booster is a PCB module measuring 127 x 77mm. It will need to be housed in a suitable case but it does not require any heatsinks or fan cooling. It needs to be teamed with a DC power supply capable of delivering 16-18V and 10A.

The booster module has six LEDs to indicate its status and a piezo beeper which can sound a number of alarms if fault conditions occur on the layout.

Circuit details

The full circuit is shown in Fig.1 and it does feature a PIC microcontroller but in this case the micro is performing something of a cameo role which we will detail later. The heart of the circuit actually consists of four IRF2804 Mosfets (Q3-Q6) which operate in bridge configuration to feed the track on your DCC layout. Made by International Rectifier, these are specifically intended for automotive applications and are rated for supply rails up to 40V DC and 75A.

They are particularly suitable for our booster design because they have a very low on-resistance; $R_{DS(on)}$ is only two milliohms (2mΩ)! That means that their power loss when conducting at 10A is only 200mW each.

Other key devices in the circuit are the 6N138 optocoupler (IC2) and the two IR2110 high and low side Mosfet drivers (IC5 & IC6).

The DCC signal from the base or command station can be either the full track voltage or the 5V signal typically available from an RJ12 6-pin or other modular connector. This connector will have pins for +5V, 0V and the DCC signal. **Either source can be used but they must be completely isolated from the circuitry in the booster.** This is where the 6N138 optocoupler (IC2) comes into the picture.

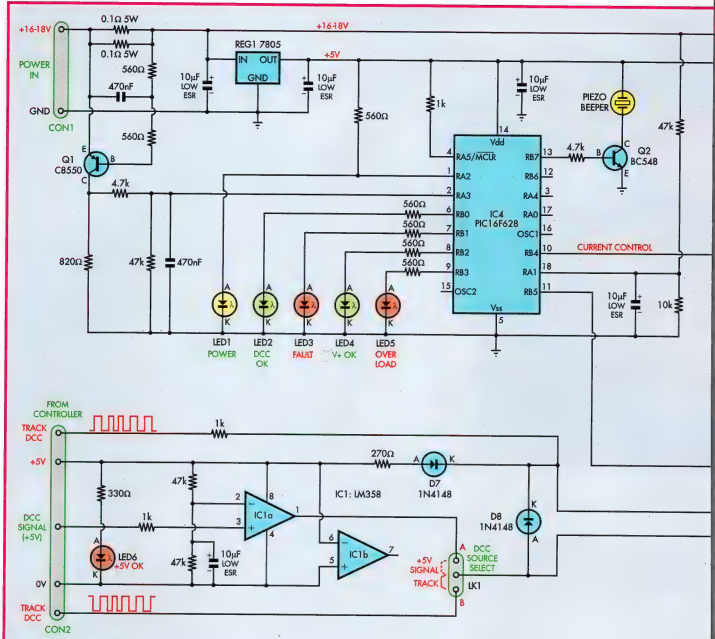
As shown, DCC track signals (if used) are terminated to two pins on CON2, each labelled "Track DCC". One "Track DCC" line is passed via a 1kΩ resistor to pin 2 of the 6N138. This is the anode of the internal LED. The cathode of the LED at pin 3 connects via the 3-way header socket to either the other "Track DCC" line or to the output (pin 1) of IC1a, one half of an LM358 dual op amp.

Alternatively, if the 5V DCC signal is used, this is buffered by IC1a which is configured as a comparator. Note that it uses the 5V supply from the base station connector. LED6 is there to indicate if the DCC 5V supply is present.

The output of the 6N138 optocoupler drives a 74HC14 hex Schmitt trigger inverter. All six inverters in the package are used, firstly to buffer the signal from the 6N138 (ie, by IC3a & IC3f) and then to generate complementary (out-of-phase) signals to drive the IR2110 high and low side drivers.

Dead-time is essential

Dead-time is essential to ensure that each pair of Mosfets (ie, Q3 & Q4 or Q5 & Q6) are not both turned on at any time. If that did happen, it would effectively short the 16V supply rail to ground and the result would range



SC ©2012 10 AMP DCC BOOSTER

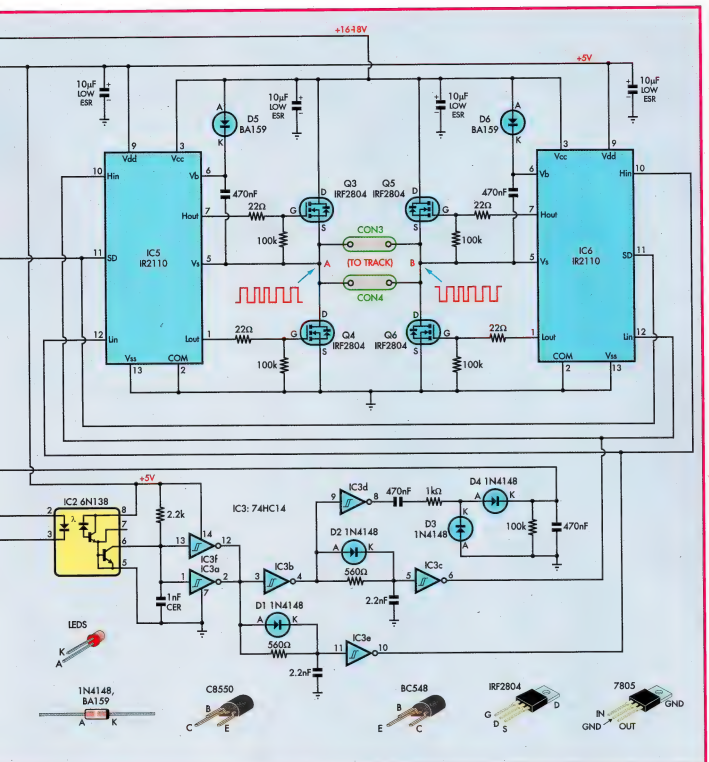
Fig.1: the DCC Booster circuit can be regarded as a high power buffer. It takes the 5V DCC or track DCC signals from a command station and feeds exactly the same pulse signal to the layout tracks with a much higher current capacity of up to 10A. And while it has a DC input of 16V (typical), it delivers a track signal of ±16V by virtue of its Mosfet bridge output stage.

from increased dissipation through to power supply malfunction and possibly even destruction of the Mosfets themselves.

Dead-time is achieved as follows. First, one signal path goes via diode D1 in parallel with a 560Ω resistor and bypassed by a 2.2nF capacitor before driving IC3e. The diode means that the positive edge goes through without delay but the negative edge is delayed by the RC filter. That means that the inverted pulse produced by IC3e has its positive edge delayed but its negative edge is not, resulting in a pulse which is shorter than the output from IC3a/f.

IC3b and IC3c and a similar diode/RC filter network are used to generate a complementary (ie, out-of-phase) pulse but in this case the resultant pulse is slightly longer. The net result is that these two pulses have "dead-time" whereby they are both at 0V each time their polarity is swapped.

So far then, we have generated suitable complementary gate signals and now we need to look at how these turn on their respective Mosfets. Note that the supply rail to the Mosfet bridge circuit is between 16V & 18V but the



typical DCC signal fed to the tracks on model railway layout has an amplitude of around 30V to as much 44V peak-to-peak. To obtain such a large signal we need to drive the four Mosfet in bridge mode whereby the 16V is alternately connected in one direction and then the other.

In practice, this done by turning on Q3 & Q6 and then turning on Q5 & Q4. In the first instance, Q3 connects one side of the track (A) to +16V and Q6 connects the other side (B) to 0V. Then Q5 & Q4 do the opposite, connecting "A" to 0V and "B" to 16V. This happens at the DCC frequency of about 4.5kHz and the resultant track voltage becomes 32V peak-to-peak.

Note that there is negligible voltage loss across the Mosfets when they are switched on, since their $R_{DS(on)}$ is so low at 2mΩ.

The high and low-side drivers, IC5 & IC6, handle the gate signals to the Mosfets. These ICs perform a number of functions. First, they take the 5V signals generated by IC3 and boost them to 16V, equal to the Vcc rail at pin 3 of each device. Turning on the lower Mosfets, Q4 & Q6, is pretty straightfor-

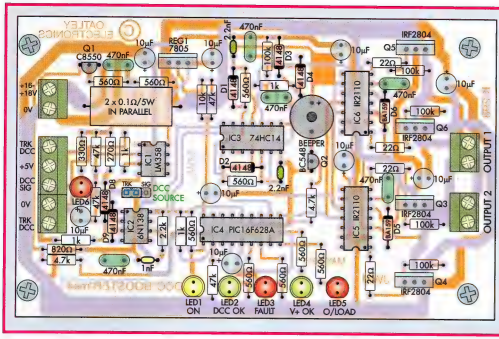


Fig.2: follow this parts layout diagram to build the DCC Booster. The LEDs can either be mounted on the PCB or on the front panel of the case that's used to house the unit.

This view shows the completed prototype. Note how the two 0.1Ω 5W resistors are installed by mounting one on top of the other.

ward really; just feed in the requisite positive 15V pulse signals which are referred to the 0V line.

But driving Q3 & Q5 is a problem because the gate pulse voltage must be 15V above the respective source electrodes, otherwise they would not turn on. The IR2110s manage this by using the switching action of the external Mosfets. For example, considering IC6, Q5 & Q6, when Q6 is turned on, the V_s line at pin 5 is pulled down to 0V and this causes the 470nF capacitor between pins 5 & 6 to be charged to V_{CC} via diode D6. Then, when Q6 is turned off and Q5 is turned on, pin 5 is jacked up to V_{CC} and it thereby pushes pin 6, the top of the 470nF capacitor, above V_{CC} by an amount equal to V_{CC} minus the voltage drop across D6.

In other words, pin 6 of IC6 is now pulled to almost $2V_{CC}$ or about 32V, assuming at V_{CC} is 16V.

So V_b is the internal gate supply for the high-side driver and IC6 connects V_b to pin 7 and thence the gate of Q5, each time Q5 is turned on. This a classic case of "boot-strap" operation.

The final wrinkle in driving the Mosfets involves feeding the gate signals from IC3's inverter stages to IC5 & IC6. For example, IC3e drives pin 10 of IC6 (and thereby Mosfet Q5) as well as pin 12 of IC5 (and thereby Mosfet Q4). Similarly, IC3c drives pin 10 of IC5 (and Mosfet Q3) as well as pin 12 of IC6 (and Mosfet Q6). This gives the alternate switching of the Mosfets referred to above.

Now we come to the microcontroller, IC4. It has a number of monitoring and control functions. The first of these involves IC3d and the diode pump involving D3 & D4. This generates a DC voltage while ever the DCC signal is present. The "DCC present" signal is fed to pin 11 of the micro. If it is not present, IC4 pulls the SD (shut-down) line to pin 11 on IC5 & IC6 high, thereby removing any DCC voltage from the tracks.

Secondly, the micro monitors the incoming supply voltage from CON1 via a resistive divider. This divider is connected across the main 16V rail and its output fed to pin 18. The resistor values have been selected so that if the DC supply drops below 10.8V, the micro again shuts down IC5 & IC6.

Thirdly, the micro monitors the current drain, using PNP transistor Q1 to sense the voltage across two parallel 0.1Ω 5W resistors. If the current drain rises above 10A, the collector of Q1 goes high, pulling pin 2 of IC4 high. Again, the micro responds by shutting down IC5 & IC6. However, the story is a little more involved at this point.

Momentary shorts across the track do not cause the microcontroller to shut off the gate switching signals because the 470nF capacitors at the emitter of Q1 and pin 2 of IC4 provide a short delay. This means that momentary shorts which can occur in a DCC layout when a locomotive crosses the points in a reverse loop are ignored – a very good feature.

Slightly longer duration shorts cause the micro to pull its pin 10 high and this shuts down IC5 & IC6. At the same time it flashes the Fault and Overload LEDs and causes the piezo beeper to sound three times. The micro then waits 4s and then pulls its pin 10 low, restoring DCC signals to the track.

However, it does this in a clever way since DCC locomotives, especially those with in-built sound decoders present a difficult load at switch-on. This is because all decoders, and particularly sound decoders, have large electrolytic capacitors following the bridge rectifier which is connected across the DCC track supply.

Typically, this capacitor is 1000µF or so but it can be 3300µF or more. So you can imagine that a large layout which might have 10 or more locomotives, with sound decoders, could easily have a total capacitance in excess of 35,000µF. When the DCC track signal of 30V peak-to-peak is applied to the track, the initial switch-on surge current can be very large, well in excess of the 10A rating of this booster circuit.

So at switch-on and when restoring power after a short-circuit, the micro does not simply switch its pin 10 from high to low. Instead, it ramps it down with a varying PWM signal over a 1.5-second period, so that all those decoder power supply capacitors are charged at a manageable rate.

Furthermore, if a short-circuit condition is maintained, the microcontroller will cycle continuously between

shut-down and then "having a look" to see if the condition has been corrected. The result is that, in the face of a permanent short-circuit, the Fault and Overload LEDs will flash, the beeper will sound three times and then it will repeat after four seconds.

These loud beeps and the flashing LEDs will leave you in no doubt that a fault is present.

Q2 drives the PCB-mounted beeper. As well as giving an audible warning when overloads occur, it gives a couple of quick beeps at switch on, as well – just because we can.

As well as static tests to verify its current rating and ability to handle short-circuits, the booster has been tested with DCC systems from various manufacturers. These included Bachmann, Fleischmann, NCE, Lenz and MRC Advance. All these systems follow NMRA standards. When 10A is being supplied to the track (using a resistive load), the four Mosfets run very slightly warm; no heatsinks are required.

However, the two paralleled 0.1Ω 5W wirewound resistors do become hot under these circumstances and if you envisage running the DCC Booster at close to is maximum rating for protracted periods, you might want to mount these two resistors off the PCB, as will be discussed in a moment. Of course, if you do envisage needing such high currents for your DCC layout, that is an argument for building two of these boosters.

Power supply requirements

If you want to run this DCC Booster to its maximum you will need a DC power supply capable of delivering 15-18V (preferably close to 16V) at 10A or more. The cheapest and most compact approach will be to use a switchmode open frame supply which can be mounted in the same case as the DCC Booster itself.

If you don't need to run the booster at maximum output and can manage with, say, 7A or 8A, a laptop PC supply delivering close to 16V will be ideal for the job. Note that if you do use a laptop power supply which inevitably will not be able to supply the full 10A (or more), you will need to change the point at which the DCC Booster's overload circuit cuts in, otherwise any overload on the model layout will overload the power supply rather than the DCC Booster.

So if your laptop supply is capable of supplying 7A, we suggest reducing the DCC Booster's short-circuit current to about 5.4A by increasing the two parallel 0.1Ω 5W resistors to 0.22Ω 5W.

Alternatively, you could build a large conventional power supply with a 160VA (minimum) 12VAC transformer, a 35A bridge rectifier and a minimum 20,000µF capacitor bank rated at 25V. That will work but will probably cost more and not be as efficient as a switchmode DC supply and you would need to be sure that its

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
470nF	0.47µF	470n	474
2.2nF	.0022µF	2n2	222
1nF	0.001µF	1n	102

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (5%)	5-Band Code (1%)
❑	5	100kΩ	brown black yellow gold	brown black black orange brown
❑	4	47kΩ	yellow violet orange gold	yellow violet black red brown
❑	1	10kΩ	brown black orange gold	brown black black red brown
❑	2	4.7kΩ	yellow violet red gold	yellow violet black brown brown
❑	1	2.2kΩ	red red red gold	red red black brown brown
❑	4	1kΩ	brown black red gold	brown black black brown brown
❑	1	820Ω	grey red brown gold	grey red black black brown
❑	9	560Ω	green blue brown gold	green blue black black brown
❑	1	330Ω	orange orange brown gold	orange orange black black brown
❑	1	270Ω	red violet brown gold	red violet black black brown
❑	4	22Ω	red red black gold	red red black gold brown
❑	2	0.1Ω 5W	not applicable	not applicable

Parts List

1 PCB, code K298, 128 x 80mm
1 3-pin PCB-mount terminal block
1 2-pin PCB-mount terminal block
3 2-pin high-current PCB-mount terminals (CON1,CON3, CON4)
2 8-pin IC sockets
3 14-pin IC sockets
1 18-pin IC socket
1 PCB-mount DC piezo beeper
1 3-pin header strip (LK1)
1 shorting link

Semiconductors

1 LM358 dual op amp (IC1)
1 6N138 optocoupler (IC2)
1 74HC14 hex inverter (IC3; do not use 74C14)
1 PIC16F628A microcontroller programmed with *program boost_mk4.asm* (IC4)
2 IR2110 half-bridge Mosfet drivers (IC5, IC6)
1 C8550 PNP transistor (Q1)
1 BC548 NPN transistor (Q2)
4 IRF2804 Mosfets (Q3-Q6)
6 1N914, 1N4148 signal diodes (D1-D4, D7-D8)
2 BA159 Schottky diodes (D5, D6)
1 7805 regulator (REG1)
1 5mm yellow LED (LED1)
2 5mm green LEDs (LED2, LED4)
3 5mm red LEDs (LED3, LED5, LED6)

Capacitors

9 10µF 50V low-ESR electrolytics
6 470nF MMC ceramic
2 2.2nF greencap or ceramic
1 1nF ceramic

Resistors (0.25W, 5%)

5 100kΩ	1 820Ω
4 47kΩ	9 560Ω
1 10kΩ	1 330Ω
2 4.7kΩ	1 270Ω
1 2.2kΩ	4 22Ω
4 1kΩ	
2 0.1Ω 5W wirewound	

DC output did not exceed 18V with light loads.

Assembly

All the parts go on a double-sided PCB (128 x 80mm) with plated-through holes. The heavy current-carrying tracks on the top and bottom of the PCB are paralleled to increase their current-carrying capacity.

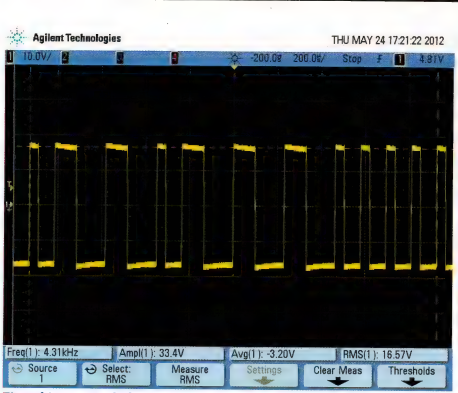


Fig.3: this scope grab shows the output waveform from the DCC Booster which had a DC input of 16V. Note that the long-term average value of DCC waveforms is 0V. This waveform can only be measured if you have a floating power supply (ie, not earthed) or an oscilloscope with differential inputs. Synchronising the scope display with a DCC waveform is very difficult; this waveform is taken with sweep stopped.

Fig.2 shows the parts layout on the PCB. Assembly is a straightforward process and you can start with the small components such as the resistors and diodes. Make sure you check each resistor using a digital multimeter as you install it. The diodes must be installed with the correct polarity. It's important that you install all components correctly the first time because removing and re-installing them on a PCB with plated-through holes is not easy.

Having installed the resistors and diodes, you can continue with the other small components such as the capacitors and the two transistors. Again, make sure that you correctly install the electrolytic capacitors and transistors and make sure you don't inadvertently swap transistors Q1 & Q2. The DC piezo beeper must also be installed with correct polarity.

Mounting the 5W resistors

You need to decide whether you want to mount the two paralleled 0.1Ω 5W resistors on the PCB or not, in view of the fact that they will get quite hot if you run the DCC Booster up to its maximum 10A rating. If you decide to mount them on the PCB, first piggy-back and solder them together before soldering the combination into the PCB. The piggy-backed resistor must be spaced off the PCB by about 4-5mm, to improve ventilation and prevent eventual discolouration (of the PCB).

Alternatively, if you are going to run the DCC Booster at close to its maximum ratings, use an aluminium-clad 0.05Ω 10W chassis-mount resistor such as this one from Element14: **http://au.element14.com/te-connectivity-cgs/ths10r05j/resistor-al-clad-10w-r05-5/dp/1259281?Ntt=125-9281**

Such resistors are not expensive and by mounting them on the metal chassis of the finished DCC Booster, you can be sure that they will always run reasonably cool.

With the sensor resistor wired in, you can fit the PCB-mount screw terminal connectors. Two types have been specified: low current for CON2 and high current for CON1, CON3 & CON4. The low-current connectors are not critical but the high-current types should be rated at 16A. As you can see in the photos, they are substantially taller than those used for CON2.

You can either mount the LEDs on the PCB or, as we think most constructors will, mount them on the front

Where To Buy A Kit

A complete kit of parts is available from Oatley Electronics who own the copyright for this kit. Cost of the kit is $70 plus $10 for postage & packing.

Fully constructed and tested units will be available on request. These units will come with a 6-month warranty. Cost will be $100. Contact the project designer via email for details.

Oatley Electronics can be contacted by email at **sales@oatleyelectronics.com** Kits can also be ordered by phone on (02) 9584 3563 or by logging onto their web site: **www.oatleyelectronics.com**

All technical enquires can be forwarded to the project designer at **jeffmon@optusnet.com.au** All enquires will be answered but please allow up to 48 hours for a response.

panel of the DCC Booster's chassis or case so that their indications can be clearly seen.

The last components to be installed are the four IRF2804 Mosfets. By the way, don't use substitutes for these devices unless you know that their $R_{DS(on)}$ values are at least as good as those specified here.

Initial tests

At this stage leave the microcontroller (IC4) out of its socket. First, connect a 16-18V DC supply to CON1. You don't need a heavy current supply at this stage. Switch on the power and check that 5V DC is between pins 8 & 5 of IC2, pins 14 & 7 of IC3 and pins 14 & 5 of the socket for IC4 (the microcontroller). This checks the function of the 7805 5V regulator, REG1.

If all is OK, switch off and insert the microcontroller into its socket. Make sure the jumper link at LK1 is set to position B, ie, to select track signals. Note that no DCC signal should be connected at this stage.

Switch on power and check that all the LEDs come on for about 1s and that the piezo beeps twice. The Fault and DCC OK LEDs should then flash and the piezo should also sound twice every few seconds. If that happens, then so far so good.

You can now connect a DCC signal source (or a square-wave oscillator set to 4kHz with an amplitude of about 12V) to the "Track DCC" pins on CON2. Now switch the power on again. All LEDs should flash and after a few seconds the "DCC OK" LED should be steady and the Fault LED should be off.

Now slowly wind the supply voltage down to less than 11V. The Fault LED and the "V+ OK" LEDs should then flash alternately and the beeper should give one beep every four seconds or so. At the same time, the micro will have shut down the Mosfet drivers, IC5 & IC6. You can check this by measuring the voltage at pin 10 of IC4; it should be close to +5V.

If the DCC Booster has performed as stated so far then it is a safe bet that the it is working correctly.

Switch off and set the jumper link to position B, ie, connecting a 5V DCC signal. This can be supplied from the 5V connector on your DCC command station or it can be a 5V 4kHz square-wave (DC-coupled) from a function generator. Connect it to the appropriate terminals on CON2 and you will also need to connect a separate 5V supply to power IC1.

Now the DCC Booster should perform as before. Of course, if you are not going to use this facility, there is no need to test it. In fact, you could omit all the components associated with IC1, including diode D1 and LED6.

Overload protection check

The overload protection can be simulated using a small screwdriver to short the collector and emitter leads of Q1. The Fault LED and the Overload LED should start flashing together within half a second and the beeper should give a series of beeps every few seconds. Again, pin 10 of the micro should go to +5V.

Finally, you can connect a high current supply set to around 16V DC and run a fair-dinkum short circuit test by using a clip lead to short the output pins on CON3 or CON4. This time, you will draw sparks, the Fault and Overload LEDs should start flashing and the beeper will sound as before. Then, when you remove the short-circuit, normal operation will be restored.

That's it – enjoy. SC

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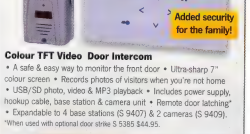

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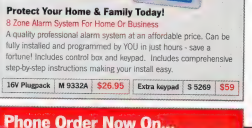

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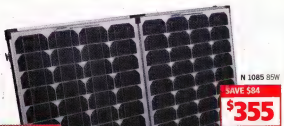

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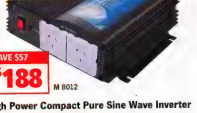

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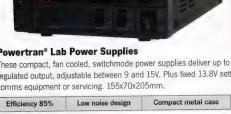

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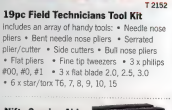

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Enhance the sound from your MP3 player

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NEW KIT!

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(SC Feb '12) This tiny regulator board outputs 1.2-20V from a higher voltage DC supply at currents up to 1.5A. It's small, efficient and cheap to build, Features low drop-out voltage, low heat generation and electronic shut-down.

NEW KIT!

K 5526 **$54.95**

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(SC Jan '12) Do you hate the way the sound level on your TV suddenly jumps during the advert breaks? Or do you find that the sound levels vary widely when switching between digital TV stations? This compressor fixes those problems by reducing the dynamic range of the signal while still maintaining clean sound. Also ideal for use with PA systems. Requires 12-30V DC power.

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NEW KIT!

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SAVE 15%

K 6011 **$25**

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Want a tiny, HIGH PO
Start with an old CD

Did you know that you can convert the flea-power motors from old CD or DVD-ROM drives to high-power operation – eg, for model aircraft or other demanding uses? While it may seem improbable it is relatively easy to do, the main change being to fit Neodymium 'Rare Earth' magnets. Oh, you also need to find some suitable motors.

I've been interested in aero-modelling for many years. When I heard whispers a while ago that I could make my own high-performance brushless model aircraft motors using parts salvaged from an old floppy disk or CD-ROM/DVD drive, at first I was sceptical.

But after doing a little research, I found that it was indeed possible. It seemed that all that was basically required was to place some so-called "super magnets" inside the motor and to replace the windings to enable higher current flow.

However, as with many projects, when I looked further into it I discovered it wasn't going to be as straightforward as I'd imagined.

I would need to find a good source of old drives, locate the required type of neodymium 'rare earth' magnets, suitable ball-bearings and would need access to a lathe.

The lathe wouldn't be a problem because my dad recently gave me his old Emco on permanent loan. Finding the right bearings also wasn't much of an issue; the types required are used extensively in the likes of model helicopters and cars and are sold in most model shops (and are also widely available online).

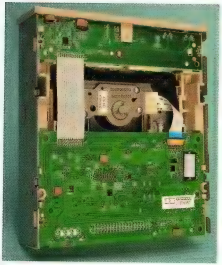
The magnet hurdle also proved easy enough to overcome since I soon found a source on the web prepared to ship as many as I wanted and so I promptly sent away for a couple of sets. The next big problem was impatience; the magnets would take a couple of weeks and I wanted be up and running today!

Sourcing parts

Since I own a computer repair company, finding old drives is not a problem; most workshops like ours have a healthy stack of them until periodic clean-outs mean we get to start on a new stack. It is worth ringing around to see what repair shops have available – and avoid those who'll want to charge you for taking away what is essentially rubbish.

One of the bigger problems you'll face is that many optical drives don't use what has become the standard-sized motor; a roughly 25-27mm diameter can/bell with an overall thickness or bell depth of around 6mm. While you can theoretically make your brushless motor from any old drive motor you salvage, many are not particularly suitable for the job, nor are they physically compatible with the standard sizes of available magnets, the majority of which have been designed to fit the 25-27mm motor mentioned above.

I stripped half a dozen old drives to get a couple of decent bells. So get



Here's a typical (if a little ancient these days!) CD-ROM drive, shown in its "as-removed-from-old-PC" state at left. The centre photo shows the controller board removed, revealing the motor in the centre (circled). Finally, the photo at right shows what we are after: the motor removed from the CD-ROM drive (via those three Phillips screws on the bracket in the centre photo) and held in the hand to show just how small the motor actually is. Despite its tiny size, it's quite a powerful little beast and, just as importantly, is very reliable (when CD-ROM drives fail, it's very seldom the motor that has given up the ghost). But even more importantly, this motor can be modified to give significantly more power output – enough, in fact, to power an electric model aircraft. And that's what we are doing in this feature.

ER brushless motor? DVD-ROM drive!

By Dave Thompson

At right: an assortment of motors pulled from various surplus drives. Note the variety of styles and sizes; while you can fashion your motor using any sized 'donor' motor, most builders use the 26mm model because the majority of available jigs and magnets are designed for this 'standard-sized' body.

as many old drives as you can while you're on the scrounge.

If you're wondering why I didn't simply work out which make and models of drive contain the right motors and look for them, rather than go through all this rigmarole, it isn't that simple.

You can take two outwardly-indistinguishable models and find they have significantly different mechanisms. The chipset and firmware might be the same but the cradle, motor and laser assemblies vary greatly from drive to drive, even within supposedly "identical" models.

Useful bits and pieces

Regarding other parts in your optical drive, there are several parts which could come in useful.

Retain the chromed shafts the laser assembly runs on, as you can use these for prop shafts. They are usually high-quality chromed steel and well worth saving, though as they are often coated with grease, you'll probably have to clean them before use.

Also take care with the laser. If your donor unit is an 8X or faster DVD drive, the laser diode is a sought-after component for optics experimenters who want them for match-lighting and balloon-popping laser projects so careful extraction is well worth-while.

I suppose you could even sell the laser for a few dollars to cover any costs you may have incurred obtaining the drive, or save it for your own evil-genius laser projects.

Then again, anyone who wants one of these has probably scrounged it themselves (and possibly discarded the motor!).

If you do decide to salvage it, take great care as I've discovered these laser diodes to be extremely static-sensitive and physically easy to damage and they are usually solidly fastened to the head assembly.

While you are breaking the drive down, there may also be many little gears, switches, bearings, belts and other bits and pieces that always come in handy so get as much as you can from each drive.

Even if the motor is not a suitable donor there are plenty of other goodies worth salvaging or passing on to someone who will use them.

Which motor type?

There are two basic configurations: in-runners and out-runners. An example of an in-runner motor is your typical DC brushed unit, in which the

A small selection of the thousands of commercial brushless motors available. They're easily distinguishable from standard (ie brushed) motors because invariaby they will have three wires – brushed motors have just two.

Standard sized bells ready for modification. Note the difference in heights. As long as you have enough material to safely glue the magnets to, any sized bell can be used. Also note the lip on the inside of the centre hole – this must be removed as described in the text.

body of the motor remains static and the armature or rotor spins – your car's starter motor is a classic in-runner type. An out-runner motor on the other hand has a fixed stator and the outside or motor body rotates instead, typically with a drive shaft connected to the rotating body to which gears or in our case, propellers are connected.

Out-runners are very efficient, which is why motors like these can deliver a surprising amount of power for their diminutive physical size. Our motor will therefore be an out-runner.

The first thing to do is break down your acquired motor. Sometimes the two halves are only held together by the existing magnet's magnetic field so pulling this type apart is very easy.

Some will have an 'R' clip, circlip or similar device holding things together. If you strike a clip version, easing the clip free will allow the two motor halves to be parted (if you get the clip off in one piece, save it for optional use later).

If in doubt, a good pull should separate the motor without breaking anything. If you find yourself reaching for a screwdriver in order to lever things apart, be very careful as it doesn't take much to ruin either component and we need both bits completely intact.

Once the outer bell is removed, you'll see it contains a ceramic magnetic ring. Also note the exposed stator remaining attached to or pressed onto the motor's circuit board (unless you've already stripped that part away).

Put the stator part to one side for the moment and let's look at the bell. Your bell may already have a shaft fixed in place, running down the centre through the stator. If so, count yourself lucky because very few do these days, however, this pretty much shoehorns you in to what style of motor you will be building; more on that later.

When the plastic disc holder, which is typically mounted to the 'top' of the bell assembly is removed (it should pry or break away reasonably easily), you should see a small-lipped hole in the centre. This will later be utilised to house our prop-shaft. Take the bell and using a small jeweller's screwdriver or similar tool carefully pry the magnetic ring out.

Take care not to distort the bell doing this; they are reasonably strong but can be easily bent out-of-round if you are too vigorous. It doesn't help that the ring usually doesn't come out easily; though it may seem like it, most are not actually glued in place, relying instead on a very tight interference fit and they sometimes take some removing.

The material the magnetic band is made of is similar in consistency to a ferrite rod, meaning they are very strong but quite brittle.

I usually just break the ring in order to remove it by using an automatic centre-punch; the type you set by turning the end to adjust the spring tension/impact energy and then push down on until it 'hammers'.

Start with a lower tension setting before cranking things up to 11 as this method seems to shatter the ring easily and a higher setting may end up ruining the bell.

Unless you really want to retain the ring for other experiments, I suggest you do the same; removal without breakage is possible but usually difficult. Once broken, the bits fall out easily.

Check the now-empty bell for any remaining debris and if necessary clean it out with some methylated spirits on a rag; we will soon be gluing to this inner surface so it needs to be as clean and contaminant-free as possible.

If your bell is one of the rare types that doesn't already have a hole in the centre of it, you'll have to make it. The hole can be drilled by hand with a suitable drill press or hand-held drill, though if you have access to a lathe, this will make the job easier and far more accurate.

If you drill by hand, be very careful to get things perfectly centred. If you don't, even by the tiniest amount, your motor will likely shake itself and anything attached to it to bits.

The hole should be the size of the intended prop-shaft and if you have retained the chromed shafts the DVD drive's laser-head assembly was running on then you already have the best item for the job. These are usually 3mm in diameter, so use a suitably-sized drill to make the hole in your bell a tight fit for the chosen shaft.

Once the hole is made, clean it up by using a counter-sink bit or a larger drill to ensure there are is no swarf left behind.

If the bell already has a hole, chances are it has a lip on the inside edge as shown in the picture . This lip will need to be removed. Again, if you have a lathe this is relatively simple, though it can also be done by hand using a larger drill bit, something in the order of a 9mm (3/8th inch).

Proceed as if you were countersinking the hole and carefully take the lip down until fully removed. The bell material is not hardened so going should be quite easy. I shouldn't need to stress that going too far will ruin things, so take it slowly.

Motor styles

At this stage you'll have to decide on what style of motor you will build, taking into account how you will ultimately mount it in your model and how you fit the prop shaft to the bell.

One configuration has the bell at the back with the prop shaft running forward through the stator/body assembly. This configuration suits bells with a built-in shaft, as mentioned above.

The second configuration is more common because more donor motors come without embedded shafts and this is the type of motor I built. This type has the bell at the front and the prop shaft runs forward through the bell to the propeller as well as back through the stator/body assembly and anchors with a circlip at the rear bearing.

The bearings are tiny – and they are also one of the most important parts of the motor, given the high speed at which it spins. It's always wise to replace any bearings with new ones – they're not particularly expensive and are available at all good model shops.

In either type of motor, the bell is fixed to the prop shaft via either two nuts or a brazed-on brass fitting and grub-screw assembly – the latter is this type I describe here.

You also have a choice of propeller mounts. You can use two nuts on a threaded portion of the shaft or you can use any of the "propeller-saver" fittings commonly used on electric model motors (refer images).

Propeller savers have the advantage that they mount using two opposing screws, meaning you don't have to thread the shaft and the prop is held on with an O-ring that loops over the prop and around the mounting screws; should you hit the ground, the prop simply flexes out of the way and hopefully doesn't break.

My advice is to avoid hitting the ground!

Mounting the prop shaft

Methods of mounting the propeller shaft requiring heat (brazing or soldering fittings onto the bell) must be done before the magnets are fitted. Some people might want to braze or solder the prop shaft directly onto the bell and this is fine, as long as it is centred and straight.

However, we have a chicken and egg scenario; fitting the shaft or shaft holder now will make placing the magnets much more difficult, especially if you don't have a jig, whereas heating the bell after the magnets are placed will ruin all your hard work.

I suggest not fixing the shaft to the bell permanently, instead using a removable system such as a brass shaft retainer. This enables you to use the same prop shaft on a variety of bells and motor bodies.

If your shaft is to be cold-fitted, that is, mounted with a couple of nuts either side of the bell, you can proceed with placing the magnets. If you want to braze a shaft-holder to the bell, you can do that now.

Using a lathe, turn up a suitable shaft holder from brass or steel and drill and tap the retaining grub-screw hole(s). Using the prop-shaft as a guide, carefully position and braze the shaft holder in place. Mount the whole bell assembly in a lathe, drill-press or even an electric drill and spin it up, checking to see everything is nicely aligned.

These motors rev like you wouldn't believe and if your alignment is out, the whole thing will vibrate badly and cause problems so you'll need to either tap it into round or re-do it until you are satisfied everything is perfectly centred and running true.

Once the shaft holder is fitted, you can now remove the prop shaft and proceed to assemble the magnets.

There are many sources on the web for the right-sized rare-earth magnets. Most of these accept Paypal or similar online payments and fire your magnets out in a small envelope as soon as payment clears.

I began buying my magnets from a US source, though this worked out to be quite expensive due to the hammering our NZ dollar was taking at the time.

I ended up importing magnets made to my own specifications and while this was an expensive exercise, I have since sold many sets to other enthusiasts at about half the price others were charging and this has helped recoup some of the costs.

There are two main types of magnets used in our motors; flat and curved.

Flat magnets tend to be cheaper and can be fitted into a wider variety of bells; curved magnets are usually designed to fit the more standard 1 inch/25-27mm diameter bell and while slightly more expensive (due to the manufacturing process), they are also more efficient.

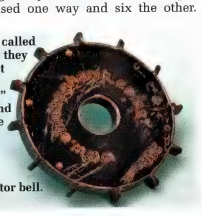
If you are aiming for maximum performance from your motor, curved magnets provide the best possible efficiency and power output.

Whatever magnets you use, you'll need twelve of them per motor and since they are very small, things can get a bit fiddly.

Refer to the images and note how the twelve magnets are placed; they are equally spaced around the circumference of the bell and their poles are reversed in alternate order, so you have, facing inward (or outwards) a north-south-north-south-north-south configuration.

It is vitally important you observe this same configuration, otherwise your motor will not run properly, if at all.

When you buy a 'set' of 12 curved magnets, you should receive six polarised one way and six the other.



(Left): they're sometimes called "scary magnets" because they are so powerful (don't get your fingers caught!). In fact, they are "rare earth" (or Neodymium) types and getting them apart can be rather tricky!
(Right): here's the little plastic jig I made up to allow accurate magnet placement inside the motor bell.

These two pics show how the new magnets are glued inside the motor bell. At left, spacers hold the magnets at the right distance apart, immediately before glueing in place. They do have a tendency to move of their own accord without the spacer. At right, this part of the job is finished, with all the magnets glued in position. Take care not to get any glue on the face of the magnets: clearances are rather tight!

Whichever magnets you use, figuring out which way they go is critical.

You don't need to know north from south, just that this side of the magnet is one pole and the opposite side the other pole, meaning the next magnet in the bell must be the reverse of the previous one.

I figure it all out during assembly by putting two magnets together; if they stick, then they are facing the same way; if they try to push apart, that's how they should be placed in the bell.

I originally placed all my magnets by hand and if you are adept at small, somewhat fiddly tasks this will not present a problem.

However I have since created a simple plastic jig which has made things easier (see the photo overleaf). If you are serious about making more than a few motors or have fingers of butter and fists of ham, I suggest a jig may be the best way to go, although it is by no means mandatory to have or use one.

I have also used spacers made from either card or plastic to separate the magnets before and during gluing, however you need to be careful you don't glue the spacer in as well as these can be difficult to remove without damaging the magnets and bell assembly.

Those wanting a jig can also approach me for this item.

Super glue

At this point we should have a quick look at the types of glues used in our motors.

Hobbyists would know about so-called 'Instant' or 'Super' glues, which are thin, fast-setting cyanoacrylate-based adhesives, marketed under a wide variety of names.

However, many people are unaware there are also gel-style cyanoacrylate glues which are much thicker in consistency and take a few seconds longer to cure then their water-like cousins.

It is this type of instant glue I use to cement my magnets in place. Not only does this give me a little more time to ensure I have things in the right position before the glue sets, I also end up wasting a lot less because it doesn't run everywhere or create problems.

Another very useful-but-optional addition to my glue tool-kit is cyanoacrylate accelerator which is used to decrease glue curing time. It usually comes in a pump-type applicator or small spray bottle and can be directed onto the area, instantly curing any cyano-based glue it touches.

A tube of thin instant glue, one of gel-style instant glue and a bottle of accelerator will suffice for all our motor gluing needs.

The magnets stick to the metal side of the bell quite well by themselves (duh) so it is relatively easy to place the first one, hit it with a spot of instant glue and when set, carefully place the next one, spot glue it and so on until all are placed.

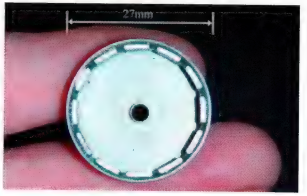
Trying to put all the magnets in and align them before gluing usually ends up like a comedy skit, with your magnets suddenly jumping about before clicking together to form a single column stuck to the bell and all facing the same way.

Keep in mind that these magnets are unbelievably strong for their size and given any chance at all will move just where you don't want them to. If you do happen to end up with a magnet "stick", pulling them apart is virtually impossible – they need to be "slid" sideways off each other.

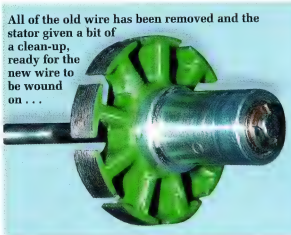
Just be careful that you don't get any flesh between them if they snap together or you might be tempted to say some very naughty words (like bother, crummies, oh dear, etc).

I found that carefully placing and securing each magnet before moving on to the next is the best way to proceed as it keeps everything under control and also allows me to get my magnet positioning right.

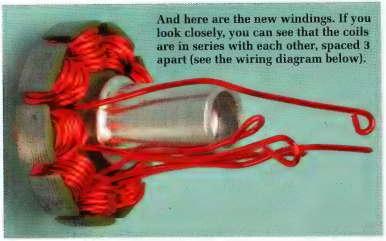
Once you've done this a few times, it gets a lot easier and having a jig to hold things in place as well is a definite advantage. Keep in mind that while magnet spacing is not hyper-critical, (it really doesn't matter if you are off a half a millimetre here or there), performance can suffer if the magnets are too far out of line so try to be as accurate as you can. Again, a jig helps here.



Here's another view of the completed motor bell and magnets sitting on the author's fingers . . . giving a good idea of just how small these motors are!



All of the old wire has been removed and the stator given a bit of a clean-up, ready for the new wire to be wound on . . .



And here are the new windings. If you look closely, you can see that the coils are in series with each other, spaced 3 apart (see the wiring diagram below).

When you have all twelve magnets tacked in place, go around and if necessary add another spot of glue under and between each one to be sure everything is well-anchored in.

Flat magnets will usually have a slight gap under their middle, with only the ends touching the bell and this gap should be filled with a drop of gel glue as well.

Once done, run the thin glue all around to fill in any gaps and hit the whole thing with your glue accelerator. This should set things nicely and result in a solid mass holding the magnets in place.

Just make sure you put all the glue drops in before giving it a spray as the accelerator will instantly cure any liquid glue it touches, even that coming out of the tube or on your fingers! (You can also buy cyanoacrylate solvent if the worst comes to the worst).

Also make sure no glue encroaches past the inside-facing surface of the magnets as things run very close and the rotor binding on the stator is one sure way to damage your motor and potentially burn out your speed controller. By now your bell should have all the magnets glued in place and be ready for the shaft to be assembled.

Mounting the prop-shaft is one of the critical parts of the job because it must be centred and dead straight. If you brazed a shaft holder as described earlier, yours is already done, however if your bell has room and you are taking the locking nuts route, then you've a bit more to do.

Find some appropriate low-profile nuts and thread the back end of the prop shaft you are going to be using to suit.

Mount the bell using one nut on the inside and one (preferably a "Nylock" or similar locking nut) on the outside. Tighten fully and spin up the assembly as described above.

It should be nice and balanced with no wobbling or wandering out of round. If it is out, tap the high side gently with a light (rubber) hammer and try again, repeating the process until it runs true. Once done, put it to one side as you are now ready to wind the stator.

Important note

The prop shaft will be exposed to some very high stresses and possibly temperatures as well. Do not just glue it in place because this can only end in tears – very likely your own – when it flies off and hits you.

As mentioned, these motors are surprisingly fast so whichever method you use, the prop shaft must be mechanically very well secured to the bell.

The motor body

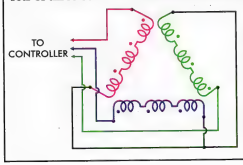
Now is the time to decide on the body style and mounting configuration you will use.

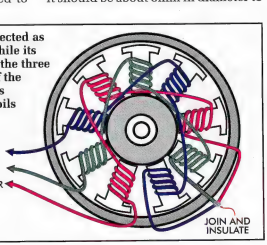
Both use the same simple turned aluminium body, though the Top Hat/bulkhead mounting method requires more lathe work than the other clamp-style mounting system so it is up to you which one you use.

Both methods require an aluminium cylinder, turned from 10mm or similar aluminium stock, which will become the motor body.

The body must be fabricated so that it press-fits into the hole in the centre of your stator. Make it about 30-35mm long and if you use a standard stator, it should be about 8mm in diameter to

Here's how to re-wire the motor – there are nine identical coils, each connected as shown here with three in series. The dots indicate the "start" of the coil while its end connects to the start of the next coil and so on. The "starts" of each of the three sets of three coils then connect to the motor controller, while the "ends" of the three sets all connect together, as shown here. Always wind the coils in the same direction, starting at the outside and working towards the middle of the stator. Wind as tightly and as neatly as possible for maximum power.





ensure a perfect interference fit.

Each end of the shaft then needs to be turned to fit your choice of bearing. If you retained the chromed shaft from your donor CD/DVD drive, the bearings should have a 3mm inside diameter to accommodate the shaft and about a 6mm outside diameter.

As mentioned, these are standard-sized bearings as sold for replacement parts for model cars and helicopters and as such are easily sourced and inexpensive.

If you chose something different for your prop shaft you'll need to source bearings that will suit it.

This is where engineers can have a lot of fun making their motor bodies from whatever material and parts they may have lying around in their bits boxes.

The only considerations are strength and weight – we want to make the motor strong enough while keeping it as light as possible.

Winding the stator

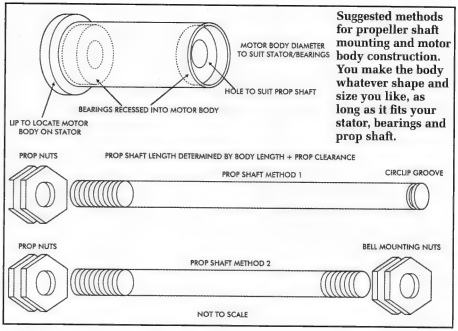
Now take the stator an push out any centre and strip any PCB or other mounting material from it along with the existing wire until you are left with a naked unit.

It is best to start with known working configurations and if you want to experiment from there, fine.

I recommend starting with 10 to 13 turns of 0.4mm enamelled copper wire, wound as neatly as possible. You can use more turns of a lighter wire or less of a heavier wire (anywhere from 0.25 to 0.5mm or larger).

It is essential you follow the winding directions exactly and wind the same number of turns in the same direction on the correct arms of the stator; any discrepancies here are as potentially damaging as mechanical imbalances.

Once wound, you'll need to connect the stator windings to your speed controller. There should be three free 'ends' that will need connecting and the easiest way to do this is with a strip of Veroboard with the appropriate tracks drilled.



Suggested methods for propeller shaft mounting and motor body construction. You make the body whatever shape and size you like, as long as it fits your stator, bearings and prop shaft.

Simply cut a piece wide enough for your motor body with a track to spare each side and make sure the strips run length-wise. Drill a hole closer to one end big enough to fit your motor's body and break the tracks where required with a 3mm drill bit to create three separate connections near the other end of the board.

Make the hole a reasonably tight fit for your motor body; while there are usually no significant stresses or strains on the connector board, gluing should not be necessary but if you do encounter movement, a spot of instant glue should suffice.

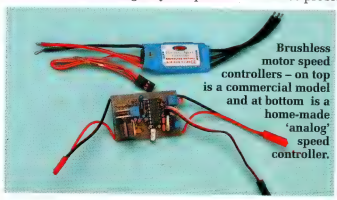
Carefully cut your windings wires to length and scrape the insulation using a hobby knife or similar. Tin the bare leads well before soldering to your connector; high-resistance joints here will cause problems.

Setting it all up

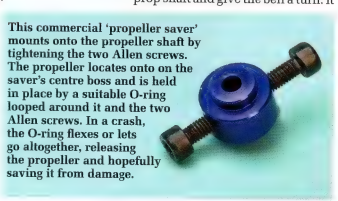
By now your motor body should be complete; the windings wound, connector board fixed and the leads nicely soldered. All that remains is for the magnet/bell/prop shaft assembly to be sized and fitted.

This is how I set mine up:

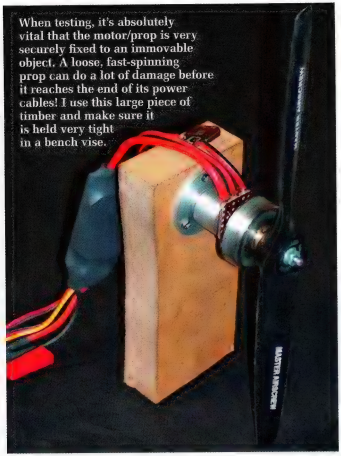
- I fit the prop shaft loosely through the brass shaft holder and feed enough of the shaft through the bearings in the motor body until it clears the end of the back bearing.
- I have already turned a groove into the end of the prop shaft in order to accept the circlip and I then fit the circlip.
- I push the shaft toward the front of the motor, (the prop end) until the circlip is flush with the back bearing.
- I then push the bell/magnet assembly down the prop shaft until it sits nicely over the stator but doesn't rub against it.
- I nip up the grub screws holding the prop shaft and give the bell a turn. It



Brushless motor speed controllers – on top is a commercial model and at bottom is a home-made 'analog' speed controller.



This commercial 'propeller saver' mounts onto the propeller shaft by tightening the two Allen screws. The propeller locates onto on the saver's centre boss and is held in place by a suitable O-ring looped around it and the two Allen screws. In a crash, the O-ring flexes or lets go altogether, releasing the propeller and hopefully saving it from damage.



When testing, it's absolutely vital that the motor/prop is very securely fixed to an immovable object. A loose, fast-spinning prop can do a lot of damage before it reaches the end of its power cables! I use this large piece of timber and make sure it is held very tight in a bench vise.

should feel totally free but magnetically 'lumpy', the lumpier the better.

Any rubbing must be investigated and dealt with before applying power. Fine tune the bell position on the shaft if necessary. The bell should definitely NOT rub on the windings.

- I then measure how long I want the prop shaft to be and mark it – you can make it any length to suit your models and mounting methods (within reason of course). I remove the shaft from the motor, cut it to length and then thread it for fitting the prop nuts.

If you are using a propeller saver device, simply cut the shaft to length and then round the end of the shaft using a file or sander.

You can now mount the propeller. Your motor is finished and ready to mount and test.

Testing

If you are using a metal clamp style arrangement to hold your motor, take care you don't squeeze too hard or short the connector board. If you are using a 'top hat' bulkhead mounting system, make sure the grub screws are tight and evenly clamping the motor body.

Over-tightening either mounting system may damage the aluminium motor body so take care not to overdo it.

Wire up your speed controller, R/C receiver (or servo simulator) and LiPo battery as you normally would.

For safety, I always mount a 15A miniature car fuse in one of the speed controller's lines to the motor. LiPo batteries as used in models like this can pump out some astonishing currents and a simple 50c fuse can save a lot of grief!

Mount the motor solidly in a vise, test rig or your model and switch on all your R/C gear.

Plug in the motor's LiPo battery, making sure you keep well clear of the propeller.

Most modern speed controllers have a protection feature built-in which won't allow the motor to run at all until the throttle is set to absolute zero, (check your trims as well) but some older speed controllers do not have this facility.

If all looks good, slowly apply some throttle and your brand new motor should leap into life. If you want to get serious about experimentation, a full test rig with a tachometer, voltmeter and ammeter installed is the only way to really fine tune your propeller, wire gauges and number of turns combinations.

Typically, though, you'll just want to get the motor into a plane and go flying and trim it out from there. Whichever way you do it, you have just created a well-performing brushless motor out of junk and that is a satisfying achievement!

Propellers

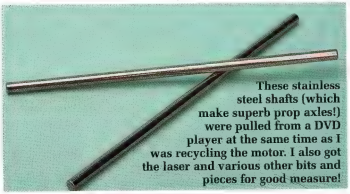
Propeller size depends greatly on the size of the motor you've made, the number of windings and the gauge of the wire used.

If the prop is too small, the motor may rev too high; too big and it might not rev enough and a heavy prop may cause electrical overloading and overheating.

Either condition may damage the motor, especially if you run it at high speed in a test rig without adequate cooling.

Note that the prop blast is *not* usually sufficient to keep things cool when the motor is static at higher revs so take care when giving it the beans on the bench.

I started with a couple of props, one a 6 x 3 (6 inches diameter and 3-inch pitch) and the other a 7 x 4. On my motors, the smaller prop allowed for very high revs but not a lot of performance in my model. The 7 x 4 suited it much better and the model flew very well with it while keeping the revs and temperature down. **sc**



These stainless steel shafts (which make superb prop axles!) were pulled from a DVD player at the same time as I was recycling the motor. I also got the laser and various other bits and pieces for good measure!

And here's the completed assembly, ready to go flying . . . oh yeah, you might also need a plane, a controller, a battery, a radio control unit and a nice large field . . .

Get thousands of capacitance values with this . . .

6-Decade Capacitance Substitution Box

By NICHOLAS VINEN

When breadboarding or prototyping, sometimes you need to experiment with a capacitor value. Substituting a range of different capacitors can be a bit tedious. What you need is a capacitance decade box, which makes it easy to find the right value for your circuit.

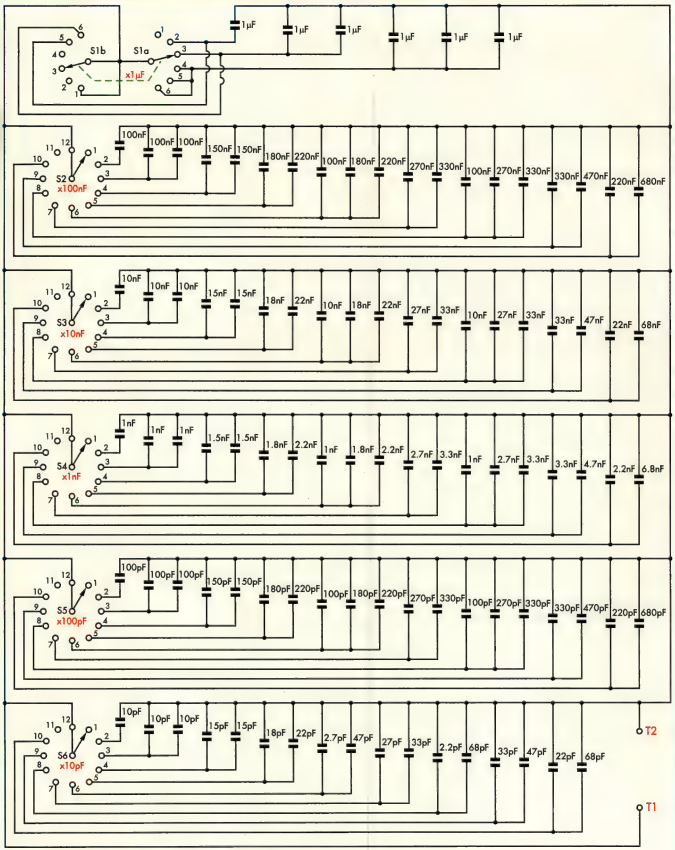
OUR 6-DECADE RESISTANCE Substitution Box described in April 2012 lets you easily find the right value for a resistor in your circuit. Sometimes though, you also need to vary a capacitance. For example, you may have an RC oscillator where the resistor is integrated in an IC so you can't change it.

For whatever reason, when you need to tune the value of a capacitor, this new 6-Decade Capacitance Substitution Box is ideal. It gives you hundreds of thousands of different capacitance values to play with, from about 30pF to 6μF. It can be used to tune oscillators, filters, time delays, compensation networks, rise and fall times, AC-coupling stages, rail-splitters, feedback loops and so on.

Even in situations where you can calculate the required value of a capacitor, you may still need to tweak it to work in a real circuit.

Design

A capacitance substitution box is slightly trickier to design than a resistance substitution box. Because resistor values sum when connected in series, a rotary switch can be connected to a resistor string giving you a variable "tap" point. For example, with 10 x



SC CAPACITANCE DECADE BOX

Fig.1: the circuit for the Capacitance Decade Box consists of just six rotary switches, two binding posts and a bunch of different non-polarised capacitors. Sets of capacitors are paralleled to give the values required and switches S1-S6 select one set for each decade. The selected sets are connected in parallel, giving the required capacitance across binding posts T1 and T2.

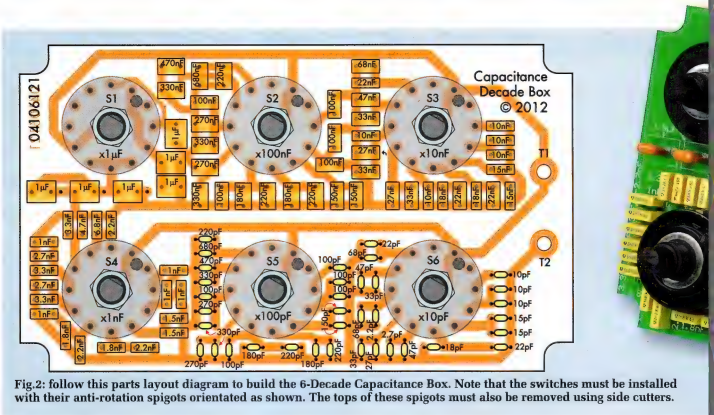


Fig.2: follow this parts layout diagram to build the 6-Decade Capacitance Box. Note that the switches must be installed with their anti-rotation spigots orientated as shown. The tops of these spigots must also be removed using side cutters.

100Ω resistors and an 11-position rotary switch, you can select a resistance in the range of 0-1000Ω in 100Ω steps.

But connecting capacitors in series gives a different result: two 100pF capacitors in series gives 50pF, three gives 33pF, four 25pF and so on. The resulting values aren't multiples of 10 and even if the values were convenient, there's the additional problem that the more capacitors you put in series, the larger they need to be for the whole string to have even a modest capacitance.

So we need to connect capacitors in parallel to make a substitution box. In practice, this means we need 10 sets of capacitors per decade, with values of (for example) 100pF, 200pF, 300pF, etc. Each switch selects one set for that decade and the decades are wired in parallel so that the capacitances combine. For example if you select 300pF with one switch and 2nF with another, that will give you 300pF || 2nF = 2.3nF.

Because capacitor values are assigned logarithmically, to get decimal values, we need one, two or three capacitors in parallel. For example, 300pF can be made using two 150pF capacitors while 400pF can be made with 220pF and 180pF capacitors. We have used values from the E6 series where possible as these are the most common ones. A few values from the E12 series have also been used, where necessary.

Circuit description

The full circuit is shown in Fig.1. There is one rotary switch per decade, labelled S1-S6. For the 10pF through to 100nF decades they are single-pole, 10-position switches (S2-S6) while S1 has two poles and six positions.

All the capacitors in the circuit are connected together at one end and to binding post T1. Switches S1-S6 connect the other ends of the selected capacitors to T2 while the others remain unconnected and so don't contribute to the total capacitance.

The capacitors around S2, S3, S4 and S5 are arranged identically. The only difference is in their values. The lowest range (S6) is slightly different because we can use two fewer capacitors since we don't worry about sub-picofarad errors. S1 controls the 1µF range and this is arranged a differently than the others, to reduce the number of large capacitors required.

It works the same way as the other switches to select values up to 3µF. For 4µF, the capacitors used for the 1µF and 3µF positions are connected in parallel, using both switch poles. Similarly, for 5µF, the capacitor sets for 2µF and 3µF are connected in parallel.

The result of all this is that you can basically just "dial up" a value using the six switches.

Stray capacitance

In an ideal world, the capacitance you get would be exactly what you have selected using S1-S6 but in reality, it will vary slightly, for a couple of reasons.

The first is the stray capacitance of the PCB itself which is around 30pF. This adds to whatever capacitance you have selected using the rotary switches. It is irrelevant for large values but could be significant for values below a couple of nanofarads.

The 10pF range is still useful, despite the fact that this stray capacitance is so large in comparison. It means that you can increase the capacitance in small steps (~10pF). You just need to remember to mentally add about 30pF when selecting very small values.

Then there are the tolerances of the capacitors themselves. 1% resistors are commonly available and cheap but a typical MKT or ceramic capacitor is either ±10% or ±20%. For this project, stick with the 10% types if possible.

Capacitor value variations are somewhat mitigated when paralleling similar values. Say we have two 1nF±10% capacitors connected in parallel and their errors are uncorrelated. Each

capacitor will be between 0.9nF and 1.1nF, an error of ±0.1nF. While the worst case values for the combination are 1.8nF and 2.2nF, the average error of any two capacitors is $\sqrt{(0.1nF^2 + 0.1nF^2)} = 0.141nF$ or 7.07%.

If the capacitors are of the same value and from the same batch, we can't assume the errors are uncorrelated. This effect is also less pronounced when the capacitor values paralleled vary significantly. But given the above, when we parallel multiple capacitors of similar values, we can generally expect slightly less variation in the resulting capacitance than the individual tolerances would suggest.

Using 10% capacitors, the result will be accurate enough for most purposes but if you want better accuracy, use capacitors with a tighter tolerance (eg, 5%) or else buy several of each and pick those closest to their nominal values, using an accurate capacitance meter. To be really tricky, where multiple capacitors are paralleled, you can select them on the basis of the lowest total error for each set.

Capacitor type

We use non-polarised capacitors in this project to make it as versatile as possible. MKT (metallised polyester) types are used for values from 1nF up to 680nF as they have good performance, are commonly available and have a consistently small size. Ceramic capacitors are used for values below 1nF because they are more common at these values. Those with an NP0/C0G dielectric are better; these are common for values of 100pF and below.

You can substitute different types if you prefer, provided they fit.

The 1µF capacitors can be either MKT or monolithic multilayer ceramic (MMC). MKTs have better performance and tend to have tighter tolerances but cost more and some 1µF MKT capacitors may be too large (they need to have a 5mm or 0.2-inch pin spacing).

Note that through-hole MKT and MMC capacitors generally have a voltage rating of at least 50V and this should generally be sufficient.

Test leads

The most convenient way to use the Capacitance Decade Box is to connect it to your circuit with a short pair of banana-plug-to-alligator-clip test leads. But keep in mind that the leads will have some capacitance which will be added to that from the box itself. Longer leads have more capacitance so keep them short.

The leads also have some inductance (as does the PCB). In practice, this limits the use of the box to circuits operating at up to a few megahertz, ie, it may not be suitable for use with some RF circuits, mainly because of stray capacitance.

Parts List

1 PCB, code 04106121, 146 x 86mm
1 PCB, code 04106122, 157.5 x 95mm (front panel/lid) OR
1 front panel label
1 UB1 Jiffy box (Jaycar HB6011, Altronics H0201)
1 2-pole 6-position rotary switch (S1)
5 1-pole 12-position rotary switches (S2-S6)
6 16-20mm knobs to suit S1-S6 (Jaycar HK7762, Altronics H6042)
2 captive binding posts (Jaycar PT0454, Altronics P9254)

MKT Capacitors

6 1µF MKT or monolithic ceramic (5mm lead spacing)

1 680nF	3 22nF
1 470nF	2 18nF
3 330nF	2 15nF
2 270nF	5 10nF
3 220nF	1 6.8nF
2 180nF	1 4.7nF
2 150nF	3 3.3nF
5 100nF	2 2.7nF
1 68nF	3 2.2nF
1 47nF	2 1.8nF
3 33nF	2 1.5nF
2 27nF	5 1nF

Ceramic Capacitors*

1 680pF	2 47pF
1 470pF	2 33pF
3 330pF	1 27pF
2 270pF	2 22pF
3 220pF	1 18pF
2 180pF	2 15pF
2 150pF	3 10pF
5 100pF	1 2.7pF
2 68pF	1 2.2pF

***Note1**: C0G/NP0 ceramic capacitors preferred*

***Note 2:** the PCBs are available from the SILICON CHIP Partshop*

Construction

The Capacitance Decade Box is built on a 146 x 86mm PCB coded 04106121 which fits into a UB1 jiffy box. Construction is easy; simply fit the capacitors where shown on the overlay diagram (Fig.2). Start with

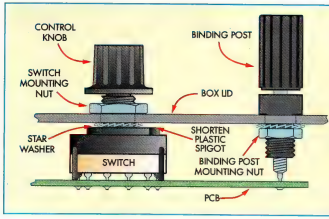


Fig.3: the PCB is secured to the back of the lid by resting it on the tops of the switches and doing up the switch nuts. The binding post spigots are then soldered to their pads.

the lowest profile MKTs, then mount the ceramic capacitors and the rest of the MKTs.

Before fitting the switches, remove the small plastic spigots that protrude from the base using side-cutters (see Fig.3). Clean up with a file, if necessary, then cut the shafts of all six switches to a length of 10mm. This is easily done by clamping the shaft in a vice and cutting it with a hacksaw. File off any burrs.

The switches can then be soldered to the PCBs. Make sure the 2-pole switch (S1) is fitted with the orientation shown in Fig.2. All the switches must be mounted flush with the PCB; check before soldering more than two pins.

Housing

You can either drill the box lid and attach a front panel label or else purchase a pre-drilled and screen printed PCB which replaces the plastic lid (157.5 x 95mm, coded 04106122). This PCB lid gives your Capacitance Decade Box a professional appearance (the front-panel PCB is available from the Silicon Chip Partshop).

Alternatively, you can download the front-panel label (in PDF format) from the Silicon Chip website, print it out and use it as a drilling template to make the eight holes in the plastic lid. A second copy can then be printed out, laminated and attached to the lid using silicone adhesive.

Next, loosely fit the two binding posts onto the lid, then remove the nuts and washers from the rotary switches. The lower washer has a locking pin and this is used to select the number of switch positions available.

To do this, place the PCB flat on your workbench, turn all the switches fully anti-clockwise and insert the washers for S2-S6 so that each locking pin goes into the hole marked "10". By contrast, for switch S1, insert the locking pin of the washer into the hole marked "6", so that it only rotates through six positions.

That done, slip the star-washers over the shafts, then push them through the lid while keeping the PCB horizontal, so you don't knock the washers out of alignment. Guide the binding post shafts through the matching holes on the PCB and then do up the six nuts tight.

You can then tighten up the binding post nuts using a small spanner and after checking that they are correctly aligned, solder them to the PCB pads. Fit the knobs and then drop the lid assembly into the box and attach it using the four provided self-tapping screws. If your box came with rubber plugs that cover the screw holes and you are not using the PCB lid, you can fit them now.

Using it

As stated earlier, the Capacitance Decade Box is most convenient in combination with short alligator clip leads but you can also connect bare wires into the binding posts, You can even use solid-core wire so that the other end can be plugged into a breadboard.

Keep in mind that the rotary switches will have either "make before break" or "break before make" operation, depending on the type supplied. This means that if you change the capacitance while the unit is connected to a working circuit, the capacitance will briefly be either very low (~30pF) or higher than usual while switching. In most cases, this won't upset the circuit but it depends on its exact configuration.

Once you have found the optimal capacitance for your circuit using the decade box, you can disconnect the it and measure the capacitance across the output terminals. Alternatively, you can just read out the position of the switches, which should be accurate to within a few percent of the true value for settings above 1nF. SC

Capacitor Codes

Value	µF Value	IEC Code	EIA Code
1µF	1µF	1u0	105
680nF	0.68µF	680n	684
470nF	0.47µF	470n	474
330nF	0.33µF	330n	334
270nF	0.27µF	270n	274
220nF	0.22µF	220n	224
180nF	0.18µF	180n	184
150nF	0.15µF	150n	154
100nF	0.1µF	100n	104
68nF	.068µF	68n	683
47nF	.047µF	47n	473
33nF	.033µF	33n	333
27nF	.027µF	27n	273
22nF	.022µF	22n	223
18nF	.018µF	18n	183
15nF	.015µF	15n	153
10nF	.01µF	10n	103
6.8nF	.0068µF	6n8	682
4.7nF	.0047µF	4n7	472
3.3nF	.0033µF	3n3	332
2.7nF	.0027µF	2n7	272
2.2nF	.0022µF	2n2	222
1.8nF	.0018µF	1n8	182
1.5nF	.0015µF	1n5	152
1nF	.001µF	1n	102
680pF	NA	680p	681
470pF	NA	470p	471
330pF	NA	330p	331
270pF	NA	270p	271
220pF	NA	220p	221
180pF	NA	180p	181
150pF	NA	150p	151
100pF	NA	100p	101
68pF	NA	68p	68
47pF	NA	47p	47
33pF	NA	33p	33
27pF	NA	27p	27
22pF	NA	22p	22
18pF	NA	18p	18
15pF	NA	15p	15
10pF	NA	10p	10
2.7pF	NA	2p7	2.7
2.2pF	NA	2p2	2.2

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Vintage Radio

By Rodney Champness, VK3UG

The AWA 157P 7-transistor portable radio

Built in Australia more than 50 years ago, this AWA 157P 7-transistor radio is still in good condition and required only a few minor repairs to restore it to working order. It's built like a valve receiver, with point-to-point wiring and no printed circuit board.

TRANSISTOR RADIOS were well-established as a consumer item by about 1960, the year the AWA 157P was first manufactured. In fact, electronics hobbyists had been introduced to transistors as components as far back as 1954. "Radio & Hobbies" often carried ads for the Philips OC44, OC45, OC70, OC71 and OC72 series germanium transistors. These usually sold for around a pound to thirty shillings ($2 to $3).

By 1958, quite a few transistor receivers were coming into the country from Japan and Australia was also starting to produce sets at that time. These sets were quite a practical proposition if you lived in a city where one or more reasonably powerful radio stations were located.

Some of the early Japanese-manufactured receivers used a phenolic board that had holes punched through it, with the pigtails of the components wired to each other as required by the circuit. These sets were quickly followed by designs using true printed circuit boards (PCBs). However, it was necessary to be quite careful when installing or replacing parts in such early sets, as too much heat easily lifted the tracks off the board.

Australian manufacturers were slower off the mark when it came to using PCBs and the AWA 157P 7-transistor set featured here retained the point-to-point wiring techniques of the valve era, despite being circa 1960. And although the transistors were not mounted in sockets (as some manufacturers did), several are mounted through rubber grommets that are in turn fitted to the chassis.

These transistor mounting grommets are roughly located where valve sockets would be otherwise be fitted in an "equivalent" valve set. So the 157P was very conventional for its time. Compared to Japanese sets of the same era, they would have been more costly to produce.

Main features

As shown in the photos, the AWA 157P portable is built into a good-quality black leatherette and thick card case. The case front features an attractive perforated aluminium mesh, behind which is mounted a 5 x 7-inch (125 x 175mm) loudspeaker.

A hand-span direct-drive system is used for the tuning dial. This simple but reliable method was used by many manufacturers to keep prices down and is quite adequate for broadcast-band portables and other low-priced receivers.

The case itself is reasonably large. As a result, the parts are quite well spread out and access to the components is quite reasonable, which makes restoration easier. However, like most portables of the era, this set had a few problems with its case. In some places, the leatherette had become detached from the thick cardboard sections and

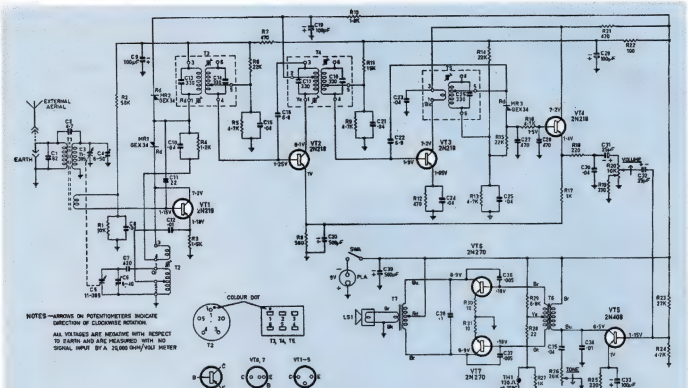


Fig.1: the circuit uses seven transistors in a fairly conventional superhet arrangement. VT1 is the converter, VT2 & VT3 are IF amplifier stages, VT4 is a preamp stage and VT5-VT7 form the audio amplifier. Output pair VT6 & VT7 are wired in push-pull configuration and are driven by VT5 via centre-tapped transformer T6.

some of the stitching around the edges had worn through.

By contrast, the set is very clean internally for its age with no evidence of corrosion. It weighs in at 3.1kg complete with battery, so it's no lightweight.

Circuit details

Take a look now at Fig.1 for the circuit details. It's fairly typical of the era, with an autodyne converter stage (VT1), a 2-stage IF amplifier (VT2 & VT3), a diode detector (MR3) and three audio stages (VT4-VT7). The output stage uses of a pair of transistors (VT6 & VT7) wired in push-pull configuration.

Power is supplied from a type 276P 9V battery. The current drain with the volume turned down is 18mA, which is slightly more than the current drain from the 90V battery of a valve portable. However, because the supply to this transistor set is only 9V it is around six times more efficient and that's before we even consider the filament current in a valve set.

It's no wonder that transistor receivers became so popular when both battery cost and weight were so dramatically reduced. Of course, the current drain did rise considerably when the volume control was turned up and could reach 45mA on peaks.

A large ferrite rod (200mm-long x 13mm-diameter) is used for the signal pick-up. In addition, the AWA 157P has provision for an external antenna and earth to boost the performance on distant stations and this scheme works very effectively.

Transistor VT1, a 2N219, is wired as an autodyne frequency converter. Its 455kHz output is fed to the base of VT2 (2N218), the first IF amplifier, via double-tuned IF (intermediate frequency) transformer T3.

From there, the signal is applied via another double-tuned IF transformer (T4) to transistor VT3, the second IF amplifier. VT3's output is then fed to single-tuned IF transformer T5 and then to detector diode MR3.

As an aside, triode valves have considerable capacitance between their grid and plate elements and will often oscillate in RF and IF circuits if they are not neutralised. Similarly, transistors have considerable capacitance between the base and the collector and may also oscillate if not neutralised. As a result, the two IF amplifier stages are both neutralised using 6.8pF capacitors C16 & C22 to make sure this doesn't occur.

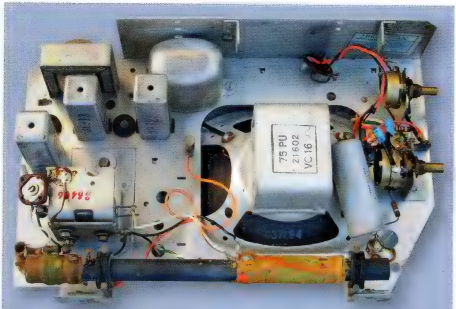
The detected audio signal is fed to the base of VT4 (another 2N218) which serves as a preamp stage. Its output is taken from the emitter and fed via a 10kΩ volume control pot to the second audio amplifier VT5 (2N408). The signal on the collector of this transistor is then fed to audio transformer T6 which in turn drives output pair VT6 & VT7 (2N270) which operate in push-pull configuration.

PNP transistors

As is typical of the era, the transistors used in the AWA 157P are all PNP germanium types. As a result, the positive terminal of the battery is connected to the chassis and all voltages are negative with respect to the chassis (ie, the supply rail is at -9V). This "positive earth" is the opposite to what we normally expect in a set and must be kept in mind when servicing some early transistor radios.

Complex AGC

As with many other transistor re-



The circuit is built on a metal chassis, similar to a valve receiver. Note that several of the transistors are mounted in rubber grommets which are in turn mounted on the chassis.

There's no printed circuit board here – just good old-fashioned point-to-point wiring that mimics valve receiver construction techniques. Despite its age (over 50 years), the chassis is still in excellent condition.

ceivers, the AGC system in the AWA 157P is more complex than is usually the case with valve receivers. The output from the detector not only has an audio component but also a DC component which increases (ie, becomes more negative) as the signal strength increases. This DC voltage (along with the audio signal) is applied to VT4 and as a result, the emitter voltage increases with stronger signals.

VT4 acts as a low-impedance DC amplifier for the AGC system as well as an audio preamplifier. A third of the DC voltage at VT4's emitter is applied to the emitter of VT2 (via a voltage divider). As a result, VT2's emitter voltage increases (from around 1V) with increasing signal strength and this in turn reduces the gain of this stage (note: VT2's base voltage is biased to 1.25V by the voltage divider consisting of R5 & R6).

In addition, the supply rail to VT2 is decoupled using R10 and C19. With no signal input to the set, the voltage across C19 is around -5.5V but this increases to around -8.2V with a strong signal as VT2 draws less current. If the incoming signal is extremely strong, diode MR2 conducts and shunts the signal that's fed to VT2, thereby further reducing the receiver's gain.

Audio amplifier design

The audio amplifier is bound to look quite foreign to an audio enthusiast today. It has only two stages and three transistors, to give sufficient audio and gain from the signal at the collector of VT4, a germanium 2N218. This was devised long before the days of complementary transistors, direct-coupled amplifiers, high negative feedback and so on. Indeed, look at the circuit and you will find that there is no negative feedback around the audio amplifier. None. So how does it work?

The signal from the volume control is AC-coupled to the base of VT5, a 2N408 transistor which is operating in class-A. It drives an interstage transformer, T6. Why would you need an interstage transformer in an audio amplifier? At the time, designers had not figured out a simpler way to generate two out-of-phase signals to drive a push-pull class-B output stage. In a valve amplifier, they would have used a "phase splitter" but trying to couple such out-of-phase signals had yet to be worked out.

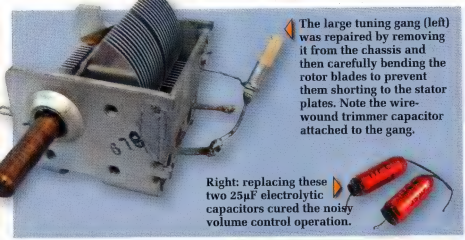
Ultimately, when NPN and PNP power transistors became available, the solution was easy but this was more than 10 years away (with complementary germanium power transistors).

The secondary of the interstage transformer is split into two halves, with each half driving the base of a PNP output transistor (VT6 & VT7). The centre tap of the secondary is connected to a resistive divider and this provides the base bias to the two output transistors which operate in class B, albeit with a small quiescent current to minimise crossover distortion.

Note that each output transistor drives only one half of the primary of the associated output transformer, T7, with DC flowing into the centre-tap and out into the respective collectors of the output transistors.

The operating conditions of the output transistors were stabilised against thermal runaway (yes, they had it in those days – they discovered it!) by the negative temperature coefficient (NTC) thermistor, TH1. It worked quite well and again, was the solution long before such circuit techniques as "Vbe multipliers" were devised.

And as far as negative feedback was



The large tuning gang (left) was repaired by removing it from the chassis and then carefully bending the rotor blades to prevent them shorting to the stator plates. Note the wire-wound trimmer capacitor attached to the gang.

Right: replacing these two 25µF electrolytic capacitors cured the noisy volume control operation.

concerned, it was more trouble than it was worth. With transformers in the circuit, the resultant phase shifts meant that only a small amount of negative feedback could be applied before instability became a problem; better to do without!

Cabinet restoration

Removing the chassis from the case is quite straightforward. The first step is to remove the two control knobs by pulling them off their shafts, followed by the hand-span dial. The latter is removed in similar fashion and was quite tight in this set but eventually came loose without damage.

The chassis itself is held in the case by three screws, one at either end of the handle and one through the bottom of the case. Once these were removed, the chassis could then be slid out through the back (after unclipping the rear flap).

That done, the case was wiped clean with a moist cloth. The next step was to repair the case where the leatherette had come away from the bottom of the rear flap. The leatherette was simply glued back onto the cardboard using contact adhesive and held in position using a couple of clamps and scrap timber until the glue dried.

The leatherette had also come away from the top edges of the case and this was repaired in similar fashion. Once these repairs had been completed, the case looked quite good. It wasn't practical to repair the worn stitching along the edges but this particular problem is not particularly obvious.

Next, the plastic hand-span dial wheel was given a polish to reduce the scratch marks that were on it. The red station indicator line had also worn away in places over the years and this was repaired by dipping a steel nibbed-pen in red paint and running it carefully along the old line. This method worked well and the indicator line now looks like new.

The dial-scale itself was also lifting along the edges so this was glued back into place using Tarzans Grip®. All that remained then was to remove the years of grime from the flutes of the knobs and this was done by scrubbing them with a nail brush and soapy water.

Circuit repairs

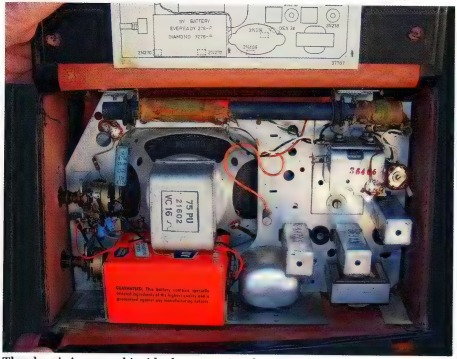
Leaky capacitors are far less critical in transistor sets than in valve receivers and it is usually safe to turn transistor sets on before doing any component replacement. The exceptions are when there is a short across the battery socket or where badly overheated (burnt) components are obvious.

In this case, it was immediately obvious why this set had been taken out of service – the stators and the rotors on both sections of the tuning gang were shorting at the low-frequency end of the dial. In addition, the volume control was extremely noisy, with many dead spots on the track.

In short, it was a bit of a basket case! However, it seemed that if I could cure both of these problems, the receiver would probably work.

The twin-gang tuning capacitor was hard to get at in-situ, so I removed all the wires soldered to it and carefully labelled them. I then removed the extension on the tuning shaft, after which I removed the tuning gang and its small adaptor plate which was mounted to the chassis. I then removed the three screws that held the tuning gang to the mounting plate.

Once the tuning gang was free, I inserted a one-sided razor blade between



The chassis is secured inside the case using three screws – two at the top and one at the bottom. The battery is no longer authentic, the case now housing six 1.5V cells connected in series in a 6-way battery holder.

the shorting plates to lever them apart. This was only partially successful and in the end I found that I had to fully open the gang and drag a finger across the rotors to bend them slightly. Finally, after some further adjustments using the razor blade, I was able to get the rotor vanes to mesh with the stators without any shorts occurring.

Having done that, I reinstalled the tuning capacitor and wired it back into circuit. As can be imagined, the entire procedure was quite time consuming but it needed to be done with care, otherwise the tuning capacitor would have been ruined.

Faulty electros

At this point, the set was tested again and many stations could now be heard but the volume control was certainly very noisy. Sometimes, spraying a volume control with contact cleaner will fix this problem but in this case it didn't work.

As many will know, volume controls in valve radios that have DC flowing through them can be quite noisy. In some sets, the volume control is part of the detector load and this was done to reduce the component count. In other cases, the control becomes noisy because of leaking capacitors.

Electrolytic capacitors are used to couple between the audio stages in most transistor receivers and although they do have some leakage, this is not usually a problem. In this receiver though, they were the problem and replacing C31 and C32 (both 25µF electrolytics) completely eliminated the noise.

In fact, these two capacitors were so leaky that I decided that it would be a good idea to replace all the electrolytic capacitors where leakage might cause a problem. These included capacitors C9, C19 and C29 (all 100µF).

Alignment

The IF transformers in the AWA 157P provide better selectivity than those in many other transistor receivers. The first two IF transformers (T3 & T4) are double-tuned, while the final IF transformer (T5) has one tuned circuit (and one tuning slug).

To align the set, I first tuned to a weak station and endeavoured to adjust all five IF transformer cores for best performance. One core, however, was jammed and couldn't be adjusted, so I had to adjust the other four around the frequency that it was set at. Fortunately, it was very close to 455kHz and the remaining tuned circuits were also very close to this frequency, so not much adjustment was needed.

The oscillator tuned circuit was next on the list. As it stood, the stations were quite close to the locations marked on the dial-scale and it was only necessary to remove a couple of turns from the wire trimmer used in the oscillator circuit to get them spot on. Unfortunately, I was unable to free the tuned winding on the loopstick antenna to adjust it at the low frequency end of the dial, as the locking "gunk" used on it had penetrated between the inside of the coil former and the ferrite rod itself. However, it does appear to be quite close to optimum.

Finally, the trimmer was adjusted at the high-frequency end of the dial and once again little adjustment was required. So it looked like AWA had used good-quality components in the tuned circuits.

Making up a battery

All of my testing was done using a small regulated supply to power the receiver. However, in order to use it as a portable, it was necessary to make up a battery pack since the original 276P 9V battery style is no longer available. This was done by fitting six 1.5V AA cells to a 6-way battery holder and inserting it inside an old 276P battery casing to keep it looking original.

By the way, while testing the receiver on the regulated supply, I found that it would perform quite satisfactorily down to 6V. So the battery life should be quite good at moderate volume.

Summary

This is a good-performing portable transistor radio. The only thing it doesn't do well is handle very strong signals. Certainly, an external antenna and earth could only be considered in more remote areas, away from stations.

It would appear that some modifications were done to the AGC system between production runs as my set has a slightly different circuit to that shown in Fig.1. This may have been an attempt to improve the set's performance on strong signals.

Finally, at the time it was made, manufacturers were still experimenting with construction techniques for transistor radios. The Japanese had begun using PCBs by 1960 but this technology had not yet been fully adopted by AWA. As a result, this particular set was built like a valve portable, with point-to-point wiring.

That said, it's still a well-built set that has lasted well and is worth having in a collection. SC

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See Review March 2010

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Ultrasonic anti-fouling power requirement

Your article states that the power drain for the Ultrasonic Anti-fouling Unit is 220mA at 12V. Instead of using a 12V battery at all times can I use a suitable battery charger as the boat will be in my marina and can be connected to mains? (N. H., via email).

● The circuit draws a peak current of up to 3A at 12V even though the average is only a modest 220mA. Some of this peak is provided by the low-ESR capacitors across the supply rails but you still need a supply that can deliver at least 2.5A (peak) for reliable operation.

Lead-acid battery chargers should only be used in conjunction with a lead-acid battery. If you want to avoid the use of a battery and you have shore power, the unit can be powered from a 12V DC plugpack that can deliver the peak current. The Jaycar 12V 2.5A plugpack (Cat. MP-3490) would be suitable.

Nixie clock is galloping

With regards to the Nixie Clock published in the July & Aug 2007 issues, I have found that my clock is intermittently running much faster. On one occasion, I measured the frequency at the test terminals at 191-192kHz; it should be 32.768kHz. Should I replace the crystal, the 4060 IC or the other parts surrounding the 4060? (M. M., via email).

● Try changing the 2.2kΩ resistor from the crystal to pin 10 of IC7 (4060) to 330kΩ. This will limit the voltage drive to the crystal and, in conjunction with the capacitance to ground, prevent overtone oscillation.

Using the Ultra-LD amplifier for PA work

I'm enquiring about the Ultra-LD Mk.2 Amplifier (SILICON CHIP August. 2008) which was available on a special deal recently. Would this amplifier be suitable to drive a Sound Reinforced FOH (front of house) PA System? Also, would the designated power supply for the Mk.2 be adequate to run two amplifier modules (the power supply for the Mk.3 version was stated as being able to run two modules)? (D. W., via email).

● The Ultra-LD module is quite suitable for PA work provided you do not intend using it to drive a transformer with 100V line outputs. That's because the DC offset at the output of the amplifier could cause a high current to flow in the primary of the transformer (which can have very low resistance).

We strongly recommend that you incorporate the tiny upgrade PCB that we published in the September 2011 issue, as it greatly improves the stability of the quiescent current setting. The PCB is available from SILICON CHIP for $5. You will need one for each module, so if you order two, the total cost will be $20 including postage and packing.

The power supply will be more than adequate to handle two channels in a PA application.

How does an induction motor run at half speed?

I have been reading the articles about your induction speed controller over the last few issues which have been quite interesting. Unfortunately it won't work on the items I would like to control (bench grinder + drill press). However, I have seen bench grinders advertised that run at half speed of around 1400-1500 RPM which is ideal for lathe tools. One such example is **www.carbatec.com.au/creusen-powerlinetrade-6-low-speed-double-grinder_c21618 or www.cws.au.com/shop/item/creusen-6-slow-speed-bench-grinder**

What I would like to ask is do you know what they would be doing to get the grinder to run at half speed? I am assuming it is an induction motor and

Lightning Protection For Solar Arrays Is Difficult

Have you ever considered doing an article on the protection of electronic input/outputs against lightning and surges? I'm in the solar industry and so have a lot of power and control lines running in conduits underground. We suffer quite a few lightning-related equipment and line failures. As we end up designing and building some of the control gear, usually PIC-based, we have to deal with these poor circuits getting blown by lightning every now and then.

I've found it difficult to obtain good, sound information on lightning protection. Even a general guide to earthing systems is hard to find – often one guide will contradict the next one you read. I've had good success with MOVs but don't feel comfortable with my understanding of the various voltage ratings and current limits. I've begun to look at other types of voltage suppressors as well but fitting in the research and day-to-day work isn't easy.

I greatly enjoy the magazine, especially the editor and his way out views. Reminds me of some of the old techs that I used to work with at ABC radio. (C. S., Moruya, NSW).

● Thanks for the suggestion. The whole topic is a can of worms, as you have found and we are not sure that there is any complete answer to lightning protection for solar panel arrays. It comes down to earthing the arrays as securely as possible but that won't do much against a direct or close lightning strike as induced voltages into the cables can still blow things apart, whether or not gas arresters and/or MOVs (metal oxide varistors) are employed.

it's got me stumped how they can do it. (N. C. via email).

- It is all related to the number of poles in the motor. A 2-pole induction motor has a synchronous speed of 3000 RPM and after allowing for slip, a nominal speed of around 2850 RPM. A 4-pole motor will have a synchronous speed of 1500 RPM and after allowing for slip, a nominal speed of around 1440 RPM or thereabouts. Therefore that particular bench grinder is using a 4-pole motor.

Caravan alarm with PIR sensors

I am looking to buy the Solar-Powered Shed Alarm from the March 2010 issue. It is for a caravan and I need two PIR sensors in the van; one for each section. The kit does have an additional two inputs but I need to know if I order the additional sensor, will it work as it may only be set up for reed switches? (J. N., via email).

- The Solar -Powered Shed Alarm is suitable for caravans. It could be used with two low-current PIR sensors from Altronics (SX5306), with each sensor signal connected via a diode to the high-impedance sensor input (Input 1). You also have to connect power to both PIR sensors (11.4V and 0V).

Note that standard PIR sensors can be used at the other inputs, although these will draw a much higher standby current, typically 10mA.

Large LED clock for motor-home

As a long time reader of SILICON CHIP, I cannot recall you doing a project for 12V LED clock that can run efficiently off a motor-home or caravan battery. Is such a project available? As I like off-road camping, I cannot use a mains LED clock without running a generator and I'm not sure how they would go on an inverter. Battery LED clocks are usually not practical as they would drain the battery fairly quickly but when run off a typical motor-home or caravan battery, it should be OK.

If it is a problem, then perhaps by using a press-button to turn on the display it might work. Although there are many LCD clocks around, I cannot read them without turning on a light and putting on my glasses by which time I'm thoroughly awake! I thought of modifying a mains LED clock but I believe the clock time is based on the mains frequency. The design should be based on using largish-sized red LEDs. (F. V., Ballajurra, WA).

- We published a large clock in March 1997. This had 57mm-high 7-segment LED displays, used logic ICs and operated from 12V. March 2001 also had a large 12/24 hour LED clock that ran from 12V and used a microcontroller rather than logic ICs.

Chook-House Door Closer To Stop Foxes

My wife and I live in the country and have some free-range poultry that we need to manually lock up each evening before dark so that the foxes don't eat them. I would like to have something that can detect darkness and automatically close the poultry shed door each night. A solution could possibly be extended to the opening time as well but the issue revolves around being at home and having to manually close the entry to the shed each evening.

My current thoughts point to a light sensor, an adjustable timer linked to the light sensor (capable of on/off for daylight and darkness activation) and a magnetic mechanical pin or other device to drive the door closer. To keep it simple, I was thinking of having a slide opening that uses gravity to close downwards when the pin was removed. It would require manual intervention to open the slide each day.

Finally, the unit would be battery-powered with solar charging, if possible. Do you have any suggestions? (C. B., via email).

- Believe it or not, we have already done it: the Chook House Door Controller from the June 2003 issue. It was based on a PICAXE08M microcontroller.

Yes it has light sensor and has an adjustable timer (via software) and it meets all your other requirements. If you want it to be solar-powered, check out the Solar-Powered Alarm For Sheds & Boats (March 2010) or the 12/24V MPPT Solar Charge Controller (February 2012).

We can supply back issues for $12 each including GST and P&P (Australia) or $AUD15.00 each including airmail P&P (outside Australia).

Headphone amplifier will drive loudspeakers

Would it be possible to publish a 2-headphone version of the Hifi Stereo Headphone Amplifier (SILICON CHIP, September & October 2011) for couples living in home units? (D. S., via email).

- This unit will comfortably drive two sets of headphones in parallel. In fact, as the article states, it will drive 8-ohm loudspeakers, so it could be used as a very fine stereo power amplifier in a study or a bedroom. If you wanted to drive two sets of headphones the only real problem would be if the two people wanted to listen at different levels, although this could be catered for if the headphones had their own volume controls.

Quiescent current setting in Ultra-LD Mk.3

I have just completed the Mk.3 upgrade to my Ultra-LD Mk.2 stereo amplifier. The quiescent current adjustments were done and the reading across the 0.1Ω emitter resistors was about 3-4mV on both modules.

I left the amplifier running as instructed for an hour or so and the readings remained pretty well the same but I increased the VR1 adjustments to about 7mV – as per the Mk.3 set-up article, with music playing. I then increased the volume and noticed that the current (not so quiescent now, I suppose) increased to an erratic range of about 8-16mV. Is this acceptable and is it a result of the V_{be} multiplier attempting to stabilise the current?

Also, I found that the start-up current drain on the Alpine motorised volume control which I used in

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GPS-Based Speedometer Project Not Necessary

With all of the items on "Today Tonight", "A Current Affair" etc, on people claiming to have been driving within the speed limit but being slugged with a speeding fine, has SILICON CHIP ever published a Digital GPS speedometer project which would be independent of the vehicle's drive train, etc?

At least one of the people spoken to in a recent story on this issue noted that she no longer used her car's speedo for determining her speed but rather relied on the digital speedo reading displayed by her "sat-nav" unit as this was much more accurate. I have heard that whilst the odometer might be accurate, the speedo may indicate that car is travelling at one speed when it may actually be travelling either faster or slower than indicated. I haven't checked it with my car but I have a feeling that mine may be on the slow side of the indicated speed.

If no such project has been published in the past, might a simple, basic, digital GPS-based speedo, without the bells and whistles, be a feasible, straightforward and hopefully cheap project that could be used to complement the in-dash speedo? Well, perhaps one "bell or whistle" could be added – an optional head-up display, if this is feasible and fits into the "budget priced" model being suggested. (P. M, Karabar, NSW).

● We described a GPS-based car computer in the January & February 2010 issues of SILICON CHIP. This does provide a speed readout but its main attraction is that it provides an instantaneous indication of fuel economy. You can purchase a kit from Altronics (Cat. K-1133).

However, we should also point out that GPS sat-navs in cars already give an accurate speed reading and they are now very cheap to buy. You can even buy smart phones with a built-in GPS sat-nav.

Typically, most car speedos are reasonably accurate in the range from 40-70km/h but they become progressively more optimistic as speed rises above 80km/h. For example, the Publisher's Honda Accord reads about 118km/h when the true speed, as indicated on the GPS sat-nav, is 110km/h.

In other words, the car's speedo is optimistic by +7.2%. However, it is within the relevant ADR specification. The car manufacturers could easily reprogram speedos to be much more accurate (the odometer is accurate!) but until the ADR specification is changed, there is no reason to do so.

These days a lot of drivers are aware of this speedo inaccuracy and they adjust their cruise control accordingly, to travel right on the speed limit.

my Studio Series Preamplifier was enough to burn the plug and socket pins providing power to the motor and created very unreliable control. This was corrected by hard-wiring the motor directly to the board. The unit has worked perfectly reliably for over a year now. I mention this in case anyone else has experienced the same problem. (P. S., via email).

● Yes, the current across the emitter resistors will vary with program material. With quiet music, the amplifier operates in Class-A mode and so the quiescent current includes that delivered to the speakers. But at higher power levels, additional rectified AC current flows through the emitter resistors, increasing the voltage reading (this will vary with the music). At this point, we are no longer talking about "quiescent" conditions and the amplifier is operating normally in Class-B.

We suggest that you pause or mute the music and see if the reading stabilises. If it does then you don't need to do anything. If it's still jumping around, brief excursions to 16mV are not a worry but you could still dial it back a touch. If, with no music playing, it's sitting above 14mV for long periods then we would turn the quiescent current down a little (although that level is unlikely to cause any damage, as long as the modules have good cooling).

Regarding the preamplifier, we are surprised that the motorised pot draws so much current but you will note that in later designs (eg, the Class-A preamplifier) we soldered the leads. Presumably the instantaneous current to the motor can be quite a bit higher than the average, especially if the clutch is slipping.

HDMI & DAC question

I have been following your articles on the Crystal DAC (SILICON CHIP, February 2012) and was interested in building one as I have recently purchased a new home-theatre system and am not happy with the quality of some of the CDs I have played. However, as my PVR, Blu-ray player and laptop computer all are connected to the Sony STR-DN1020 amplifier via HDMI, it occurred to me that the DAC involved is most likely in the Sony amplifier and not the DVD player.

If this is correct, there would possibly be no advantage in building this unit. Could you comment on this?

Incidentally, I have obtained some 24-bit FLAC (Free Lossless Audio Codec) files from the internet and have found these provide excellent results when played on my system from my laptop. The sound quality seems to be much better than that from my Sony PVR with the sound quality from the Sony Blu-ray slightly inferior again. All go to the amplifier through HDMI. (B. D., via email).

● HDMI transmits digital audio only so you are correct that it will be the DAC in your amplifier/receiver which is being used. Its internal DAC should be quite good and so using an external one may not give you a noticeable improvement in sound quality. But since we cannot find any distortion specs for the STR-DN1020 we can't say for sure.

Usually though, the amplifiers in this type of home-theatre receiver aren't especially good for listening to music. One of our staff members has an older but quite good Harmon Kardon 5.1 receiver (AVR7000) and its internal Burr-Brown DAC is very good. But it is possible to get a very noticeable improvement in sound quality by taking its left and right channel pre-outs (ie, the outputs of its preamplifier which are normally fed back into its internal

left/right power amplifiers) into the SILICON CHIP Ultra-LD amplifier. The receiver then drives the centre and surround channels since they normally only carry voice and effects when being used in home-theatre mode.

So if you're looking to get better sound quality your best bet is to bypass the left/right channel amplifiers and hook up a true hifi amplifier in their place. That is assuming you have good speakers; they are often the weakest link in any audio system.

As for the variations in sound quality depending on source, it's probably because the audio on Blu-Ray discs is normally compressed using a scheme like Dolby Digital or DTS. We find that Dolby Digital sound is noticeably worse than linear PCM audio. DTS is somewhere in between and normally sounds quite good.

The PVR is probably storing compressed audio too. So it is the storage method rather than the playback method that's affecting the sound quality. FLAC sound quality is identical to PCM.

ECU controls car battery charging

I recently purchased a small caravan with a gas/electric fridge. After connecting the fridge to the vehicle, I measured about a 1.5V drop at the fridge input. At a current of about 15A this was to be expected. I then had an auto-electrician increase the wire size to the trailer outlet using two 6mm cables via a 50A fuse direct from the vehicle battery and used the vehicle chassis as the earth return. I now measure about 0.2V drop at the fridge.

I have always monitored the vehicle battery voltage with a digital unit hardwired to the vehicle battery (eg, in various modes such as engine off, idle, during driving etc). The vehicle charging system output voltage at 14.2V or greater only kicks in when ancillary units are in use – eg, fan, rear demister, headlight/stop lights etc, apart from when the vehicle (a Subaru Forester) is first started. The fridge operates on 12.5-12.7V whilst driving unless one of the car's accessories is turned on when it increases to 14.2V or greater.

Is this controlled by the vehicle's ECU which senses the various ancillary units in use? I recently had the alternator overhauled due to this problem but feel I have wasted my money. What modifications are necessary to ensure the charging system senses the large drain on the battery due to the trailer fridge, to maintain the battery in top condition? (M. T., Donvale, Vic).

● Since the ECU has control over battery charging there is not much you can do to ensure the battery is kept charged at 14.2V when the fridge is running. Perhaps the best method is to drive with your headlights on. That way your vehicle would be more visible too.

Some power tools have inbuilt speed control

I recently constructed the Universal Motor Speed Controller (SILICON CHIP, May 2009) and it works just fine. I am about to buy a combination circular saw but I am being cautious, as most of them advertise "soft start", "motor speed remains constant under load" or other forms of incorporated electronic motor control features.

With the appropriate metal sawblade, I plan to run the saw at a lower speed, so I can cut aluminium. I have a lot of workshop experience (Instrument Maker, Technical Officer etc) in cutting aluminium with lathes, mills, band saws etc. My concern is regarding the inter-action between the SILICON CHIP Speed Controller and any electronics internal to the combination saw motor or its housing.

Universal motors can easily be identified by the brush gear, so purchasing the right motor seems easy enough. I have looked at the Makita LS1016, and the AEG PS305DG. The AEG only mentions that its speed remains constant under load or is this just a feature of the motor design? It does not mention soft start. (R. S., via email).

● The Universal Motor Speed Controller is best suited to motors that do not have internal electronic control. Whether an appliance will work with the Motor Speed Controller when it has some sort of internal electronic control really depends on how this control is done.

Motors that maintain speed under load do have electronic control. That constant speed control would only work within limits and the motor would reduce in RPM once the load exceeded a set amount when the full available mains is applied to the motor.

Doubt over speed controller ratings

I would like to make a few comments on the Induction Motor Speed Controller article, having spent time working in a motor and transformer rewinding shop as part of my training in the 1970s. The article is quite good but the current ratings of the control equipment are inadequate.

The basic capacitor-start, capacitor-

Wheelchair Speed Control With Two Motors

I have a 24V wheelchair that has two motors. However, because of the way that the manufacturer of the chair designed it 12 years ago, the lefthand motor turns in the opposite direction to the righthand motor but still makes the whole chair drive in a straight line. There is not much space for the two motors, with one motor per rear wheel.

Can your 24V 20A Motor Speed Controller (SILICON CHIP, June 2011) actually run two DC motors in parallel and still maintain good speed regulation via its back-EMF feedback technique? Or should I use two separate speed controllers with a dual-gang speed potentiometer on the same shaft?

I would much prefer to use one controller for both wheelchair motors and of course, the polarity to the second motor would have to be opposite to the first motor. (P. W., via email).

● It is possible to run both motors from the one controller but you may find that the wheelchair does not run in a straight path, due to slight differences in the motors.

In practice, it would be better to run each motor from a separate controller mainly so that you can arrange for direction control with one motor running faster or slower than the other for steering and straight line trim.

Note that the DC motor control does not have back-EMF speed regulation. On a heavily geared motor that is probably not necessary anyway.

Speed Control For A Scroll Saw

I'm interested in building the Induction Motor Speed Controller and probably will. I have a question about the motor in a scroll saw I'd like to control with it. The label says it is a Class E Induction Motor, 120W, 50Hz, 1400 RPM. Unfortunately, it is not branded so I can't get more information. At this stage I'm reluctant to strip the whole machine down so I can take the motor completely apart.

From what I can see, P and N go into the motor case via the power switch. A 4µF 250VAC capacitor is on the outside, with two wires going from it into the motor. With the capacitor disconnected I read 144Ω across those two wires and 45Ω across P and N. Looking at the diagrams on page 26 of the April 2012 issue, the most likely configuration looks like the Permanent Split Capacitor, with a 45Ω run winding and 100Ω start winding. What would be your take on that? (J. Q., Auckland, New Zealand).

● It probably it is a Permanent Split Capacitor type but it is difficult to be certain. Mind you, with a rating of only 120W, it would be possible to get a limited range of speed control with a Triac light dimmer/fan controller which is readily available and much cheaper.

run single-phase induction motor may be rated at 8A on the nameplate but this rating is when the motor is running at full speed of 1450 RPM (4-pole) or 2850 RPM (2-pole), allowing for slip between the magnetic field and the cage rotor.

At initial power-up the motor draws about six times the rated current until the rotor spins up to speed and provides back-EMF to reduce the current flow down to the nameplate rating. So an 8A-rated motor will draw approximately 48A at initial switch-on. Paragraph 2 on page 21 of the April issue is only allowing for control components rated at 20A. This under rating could cause major problems when a fault condition occurs. (D. S., Howick, New Zealand).

● Everything you say about normal operation of induction motors is correct. However, the controller gradually ramps up the input voltage at start-up so that currents are kept within safe limits. In fact, the controller has been designed to work with pool pumps which effectively start at full load.

45s voice recorder has glitch problems

I purchased a kit for the 45-second Voice Recorder module (Silicon Chip, December 2007) but have been having trouble with it playing the voice back consistently. It runs in 8-voice mode although only four 1-second samples are used.

It works for a few times after initial power-up but then stops. It has a glitch on M1 with a click at the start, which is why I am running in 8-channel mode and not using M2 and M3. I am using telecommunication relays to activate the board.

Can you think of any reason why it might be doing this? Could the initial trip be too short, although holding down the button doesn't fix this? Or could it be a faulty chip, since it has a glitch on M1 and works only sometimes? (J. W., via email).

● It's not easy to suggest why your Voice Recorder module is exhibiting the intermittent problems you describe but you may be right in suggesting that the contacts of the relays you are using could be responsible. To see if this is the case, try connecting a 100nF or 220nF capacitor between each of the MxEnable pins and ground. The capacitors will provide simple "contact bounce'" suppression, which may fix the problem.

If this doesn't help, it may be that your HK828 chip is faulty. However before you replace it, try connecting the "Chip Enable" pin directly to ground and see if this makes operation more reliable and/or consistent. There have been a few reports of a small number of HK828 chips needing a pull-down resistor of lower value than the 47kΩ we provided, in order to give reliable operation.

Measuring DAC sampling rate

A while ago I made the DAC project (Silicon Chip, September, October & November 2009) and often use it to play music from my Linux PC via Toslink. Some of my files are high-resolution FLAC format with music encoded at 24-bit 96kHz but I sometimes suspect the sound driver of the operating system or the music playing program can possibly down-sample the audio to 16-bit 44.1kHz, if it is not configured correctly.

Is there a simple way to measure on the DAC using a CRO or frequency counter what the sample rate and bit depth of the incoming signal is? Ob-

continued on page 104

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Ask SILICON CHIP
. . . continued from p102

viously you can't measure the SPDIF frequency directly as the clock and data are encoded on the one signal and would vary, depending on the data. (S. G., Carnegie, Vic).

● You are right; computers will often down-sample the audio to 44.1kHz/48kHz 16-bit for various reasons. The main one is so that several applications can play sounds simultaneously and these are mixed in software, at a fixed sampling rate and bit depth.

Some sound drivers let you set/query this information but you can measure it at the DAC. The left/right clock is output from the LRCKO pin of IC3 (pin 10) and this is a square-wave with a frequency equal to the sampling rate. It connects to pin 10 on the digital I/O header and thence to pin 4 of IC6 (PLRCK). You can measure this with a frequency counter or scope.

Unfortunately, there is no easy point to probe this line since it runs only on the underside of the two PCBs. You could solder a short length of solid-core wire to pin 10 of one of the 16-pin IDC sockets and have it stick out from under the board and you could then measure the frequency, relative to a convenient ground point such as a regulator tab or power supply ground terminal block screw. This short length of wire should not interfere with the operation as long as it doesn't short to anything.

There's no easy way to tell whether your sound card is outputting data with a 16-bit or 24-bit resolution. You can connect an oscilloscope or logic probe to the serial audio bus and monitor the serial clock and data lines. There are 32 serial clock pulses per sample sent; if the audio data is 16-bit, the data line will always be zero half the time whereas if it's 24-bit, it will be zero for eight pulses in a row, ie, 25% of the time.

Finally, it may be possible to get a general idea of the sampling rate from the S/PDIF frequency, especially if you are playing a silent file. The S/PDIF frequency is typically somewhat proportional to the sampling rate. SC

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Notes & Errata

Crystal DAC (February 2012): the trimpots were specified as 500Ω but should in fact be 5kΩ. This affects the circuit diagram, PCB overlay and parts list. Also, the labels for Q22 and Q23 are swapped on the overlay diagram (Fig.6, page 32).

Crazy Cricket/Freaky Frog (June 2012): the Jaycar buzzer part number is incorrectly listed in the parts list. It should be AB-3440.

Wideband Oxygen Sensor Controller (June-August 2012): the parts list in part 1 (June, p42) includes two 3.5mm stereo jack plugs. Delete these and substitute two PCB-mount 3.5mm stereo switched jack sockets.

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150mm/6"	200mm/8"	300mm/12"
$89 (Q180)	$115 (Q181)	$169 (Q182)

SBD-25A BENCH DRILL

- 20mm drill capacity
- 2MT spindle taper
- 1hp 240V motor
- Micro switch on belt cover
- 16 spindle speeds

$339 (D144)

FREE DRILL PRESS VICE (M124) VALUED AT $22

SURFACE MARKING OUT GAUGE

- 225 & 300mm spindles
- Includes scriber
- A fully hardened & ground base which serves as an accurate reference surface

$49 (M053)

JOBBER DRILL SET HSS

- 1 - 6mm range
- 0.1mm increments
- 51 piece set
- Precision ground flutes
- 118° split point

$89 (D128S)

SHEET METAL STEP DRILL SET

- HSS M2 bright finish
- For drilling holes in thin material
- Sizes: 4-12mm x 1mm, 6-20mm x 2mm, 6-30mm x 2mm

$70 (D1071)

EDBD-13 DRILL SHARPENER

- Economy drill bit sharpener
- Capable of split point sharpening
- Grinds two flute drills of unlimited length
- 80W 4200rpm 240V DC motor
- 3-13mm capacity
- 118° drill angle

$109 (D070)

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